DIMENSIONS NBS

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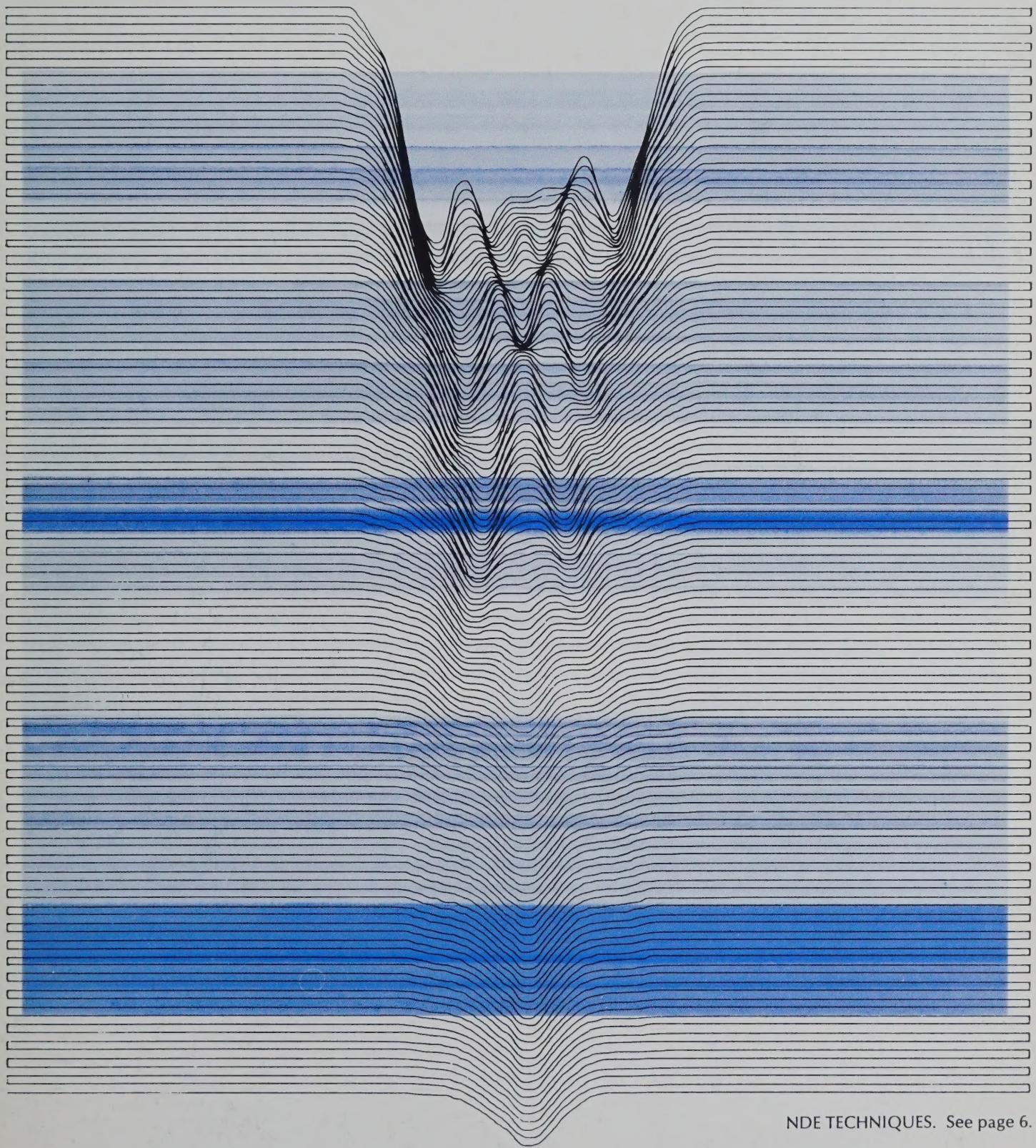
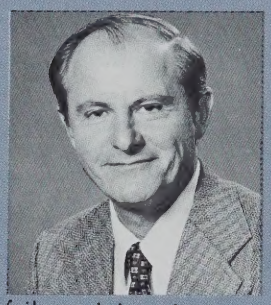


NDE TECHNIQUES. See page 6.

COMMENT

CALIBRATION FOR NDE MEASUREMENTS



Nondestructive evaluation (NDE) is a relatively new technique used in industry to assure the quality of materials, components, and assemblies. Because NDE can reveal hidden defects in materials and thereby prevent premature failures, it is an important technique for safety. Interest in NDE is on the upswing, a trend brought about by needs to improve productivity and conservation and by increasing pressures from product liability. Better procedures for NDE, involving broadly used methods such as radiography, ultrasonics, eddy currents, liquid penetrants, and magnetic particles, will play a key role as we move toward improved product quality. These NDE methods are reviewed briefly in an article in this issue, with emphasis on NBS calibration methods that are either now available or will be available shortly to help industry achieve NDE measurement reproducibility.

A growing need exists for high-reliability NDE. Metrologists in industry and government laboratories can help bring this about by providing calibration of NDE equipment and reference artifacts, in many cases with traceability to NBS. Today calibration laboratories are called upon for many different kinds of measurements in addition to those initial basic few involving mass, length, and time. A new class of measurements is appearing on the scene, one that is undoubtedly going to assume major importance—measures for nondestructive evaluation.

Nondestructive evaluation encompasses the many measurement methods that are used to examine materials of assemblies in such a way that the tested object can be used after the test is finished. This is in contrast to destructive tests in which the tested object is destroyed in order to obtain the required information (e.g., a tensile test in which the object is pulled apart). NDE methods vary from straightforward visual inspection to sophisticated approaches in which three-dimensional images of the interior of objects are reconstructed from x-ray, neutron, or ultrasonic measurements. These kinds of tests, involving optical, radiographic, magnetic, electrical, ultrasonic, and other similar phenomena, are chosen and used so as not to impair the usefulness of the tested object.

There are several reasons why NDE is important. Since the test object is not destroyed, 100 percent inspection is possible. Components involving safety considerations, such as primary components of an airplane, require testing. Similarly, critical components of automobiles, such as those in the braking or steering systems, require testing to assure safe operation. These examples point up some of the growing interest in NDE because of product liability problems. Liability considerations are encouraging many manufacturers of consumer products to use NDE more effectively.

NDE measurements in industry are, and will continue to be, on the increase because of pressures not only from product liability but also from productivity, conservation, and competition. If we can be assured that defects in a component (such as inclusions, cracks, or voids) will be only below a certain size, then the design can be tightened. This can result in savings of material, energy, and time. The impact is on both conservation and productivity. Furthermore, there is a strong economic incentive for manufacturers to produce quality products and components. Foreign competition at home and abroad is increasing. Many U.S. markets have fallen behind foreign ones, not because of price but because of a perception of quality differences.

Traceability goes a long way toward improving the reproducibility and reliability of NDE measurements. Standards and calibration laboratories fill a necessary role in this area because of the need for accurate NDE measurements—and because customers expect and often require traceable measurements. Traceability for many NDE measurements is now available in the form of calibrations and Standard Reference Materials (SRM's) from NBS.

Suggestions for additional traceable NDE measurement needs or comments on NDE procedures are invited to help NBS provide service to the quality assurance community.

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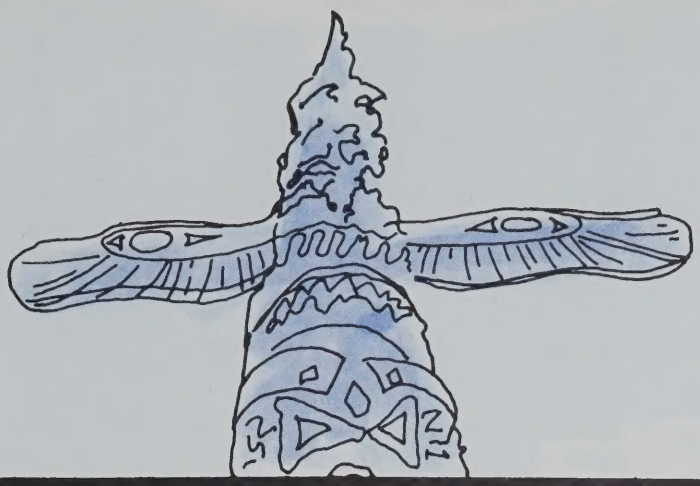


by Collier Smith

SINCE August 1977 the Trans-Alaska Oil Pipeline has carried more than a billion barrels of crude oil from arctic Prudhoe Bay south to Valdez. Eight billion barrels more remain to be delivered by the 1290-km (800-mile) pipeline, even if no more large deposits of oil are found on the North Slope.

The pipeline carrying all this oil is the result of 4 or 5 years of environmental wrangling and studies, 3 years of construction, and $7.7 billion of capital investment, probably the most expensive privately financed construction project ever completed. Small wonder that much depends upon the success of this venture.

To protect both the pipeline and the magnificent but delicate terrain through which it passes, it is necessary to prevent the failure of every single weld in the line. Consider: the oil is pressurized to 8.1 MPa (1180 psi); the 122-cm (48-inch) diameter pipeline passes over ground that has experienced some 30 earthquakes in the past 80 years; it crosses miles and miles of permafrost and some 350 rivers and streams; and the pipe may be exposed to temperatures ranging down from 57 °C (135 °F) at full flow in temperatures that may reach −50 °C (−58 °F) or lower. All these factors cause stresses in the pipeline, which might rupture if a weak weld existed, and a rupture might spill thousands of barrels of oil and result in the shutdown of the line for repairs.

Testing every mile of pipe after installation at 125 percent or more of maximum operating pressure, plus radiographic (x-ray) inspection of every single girth weld is required under the basic agreement by the U.S. Department of the Interior to help insure the integrity of the pipeline. A minimum of 10 percent of field girth welds are inspected in other pipelines (except in populated areas, at railroad and river crossings, and a few other specified places); this is the first time all field girth welds have been x-rayed in a pipeline of this size and length.

Since there are about 58 000 field girth welds along the pipeline, it is not surprising that welding flaws have been detected and either repaired or replaced. The problem is that established welding standards require the repair or replacement of some welds that actually are structurally adequate for the specific pipeline locations where they are found. This repair work is very expensive; the average weld repair after pipeline burial in Alaska costs about $70,000. If the rejected weld happens to lie under a river crossing, the cost to replace it could be many times higher.

These standards are the result of the way in which welding standards traditionally have been set. Called "workmanship" standards, they describe the largest allowable flaws (and their frequency per foot of weld) permitted in a weld. The original workmanship standards were established years ago by observing what a skilled welder could accomplish by using specified welding techniques and procedures. These standards do not take into account the actual stresses on the weld in a specific pipeline; rather, they are set to insure a satisfactory weld under all conditions along any pipeline anywhere. This means that many flaws are rejected when they actually would have no practical effect on the weld's fitness for service at that location.

When the Alyeska Pipeline Service Company ran into a situation, during an audit, that a number of buried earth welds did not meet the established standards, it began repairing most of the welds, but asked for waivers of repairs on the remaining rejected welds—especially those where digging up the line would cause silting of rivers and other environmental damage. They requested waivers for welds that had flaws in excess of the allowable size by the prevailing standards, on the basis of newer analytic techniques that showed the welds would not endanger the pipeline at those locations.

This is where the National Bureau of Standards entered the picture. As a result of Alyeska's requests for waivers, the Department of Transportation's Materials Transportation Bureau asked NBS to provide information for assessment of an alternative set of criteria for weld acceptance. Basically, the alternative criteria take into account the expected maximum stress in the specific pipeline and welding materials. Combining all this information with knowledge of the specific flaws in question (i.e.,

Smith is a writer and public information specialist in the NBS Boulder Program Information Office.

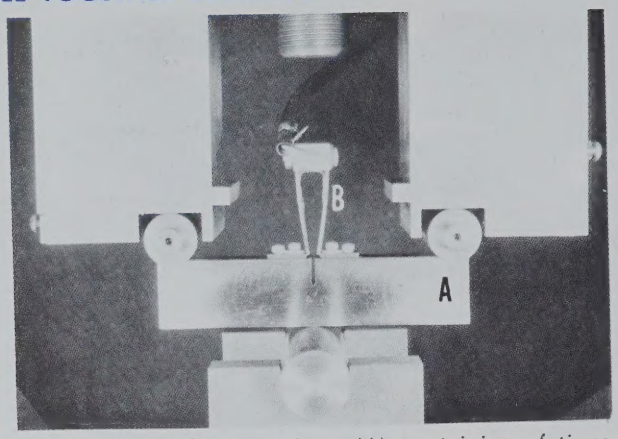
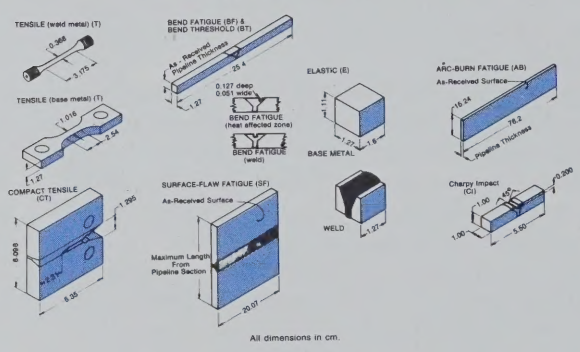


Figure 1—*A weld test specimen (A), containing a fatigue crack representative of a sharp flaw, and a displacement-measuring transducer (B), positioned above the notch with the fatigue crack, are shown in a 3-point bend test fixture. Results from this crack opening displacement rest are used to determine the fracture toughness of the weld.*

Trans-Alaska Pipeline Girth Weld Evaluation



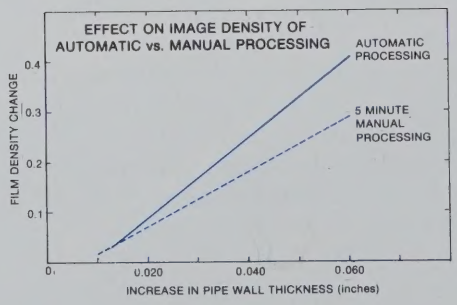


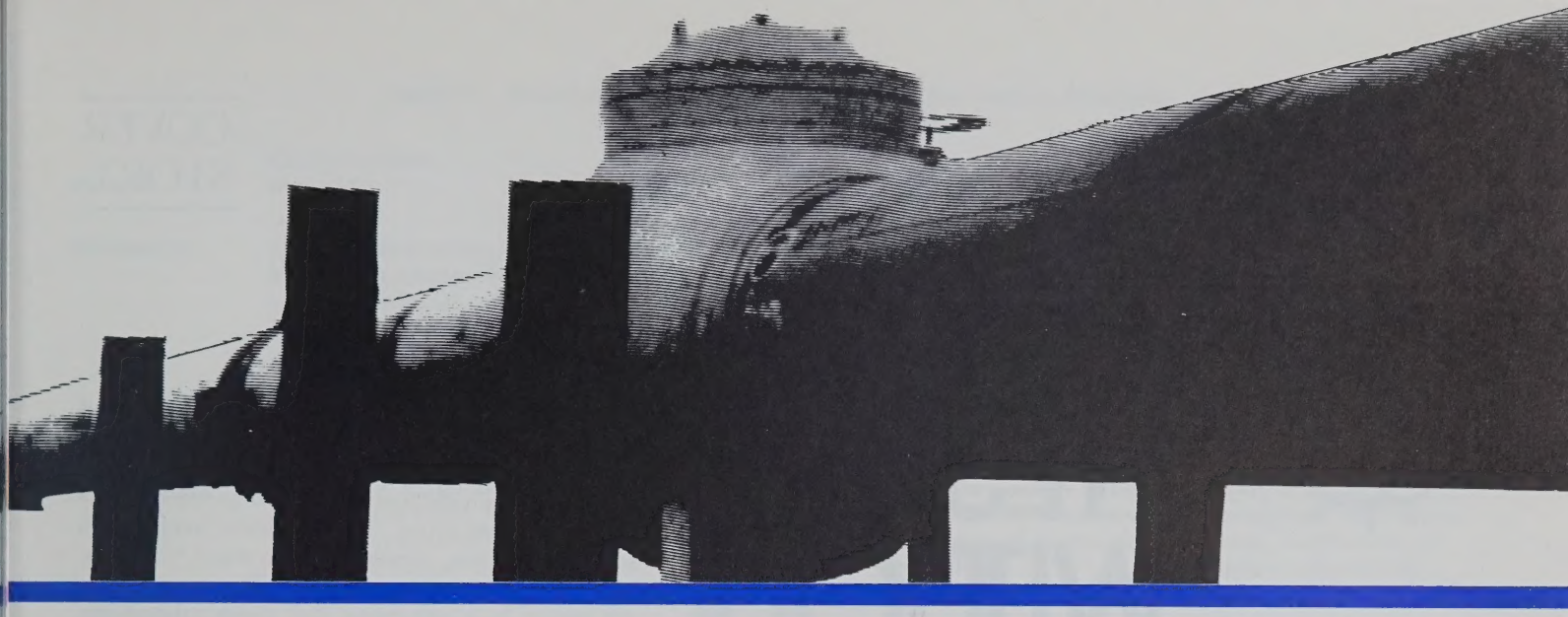
Figure 3—*The effect on image contrast of automatic versus manual processing for two identically exposed radiographs. Evaluation of contrast produced by a flaw provides the basis for most flaw depth estimates made from radiographs.*

their size and shape) allows the science of fracture mechanics to predict the smallest minimum flaw size that could cause failure of a weld in service.

An NBS team undertook the evaluation of the proposed alternative standards and in less than 4 months reported that fracture mechanics could indeed provide adequate alternative means of deciding whether specific weld flaws would endanger the safety of the pipeline. On this basis, waivers were granted on three welds located under an Alaskan river. Since Alyeska had already begun repairs on all the other welds where waivers were requested, waivers were not granted on them. Subsequently, an overall audit of the x-rays indicated that about 8 percent of the pipeline welds had flaws that exceeded in size the older workmanship standards. Again fracture mechanics was used as a basis of granting or refusing waivers for those flaws.

Now another large pipeline from the North Slope of Alaska is being built to bring natural gas to the United States midwest and west coast. It will follow the Alyeska Pipeline for the first 800 km (500 miles) or so, then diverge into Canada and head for Chicago and points west. The new pipeline will be even larger and longer than the oil pipeline: up to 142 cm (56 in) in diameter and 7700 km (4786 miles) long. Cost of the Alaskan portion (only 122 cm in diameter) was estimated by the contractor in 1980 to be over $7.5 billion.

According to the basic permit, over 90 percent of the welds in the Alaskan portion of the gas pipeline (1177 km or 731 miles of pipe) will be inspected by x-rays and other approved techniques. In the "lower 48" States, customary Department of Transportation rules will apply: a minimum of 10 percent of the cross-country welds will be inspected, with higher inspection rates for railroad and river crossings in populated areas. It is being proposed by the pipeline company that weld flaws that do not satisfy the old workmanship standards on the Alaska portion of the pipeline be evaluated by the new fracture mechanics techniques (also known as



"fitness-for-service" standards). If allowed, the new methods offer substantial cost savings without jeopardizing safety.

Again, NBS has been asked to conduct further tests and develop new inspection techniques based on fracture mechanics concepts and advanced technology. The results of the NBS program will be alternative standards for various types of flaws depending on size. The program is also intended to produce more accurate and reliable methods and procedures for measuring the size and significance of flaws.

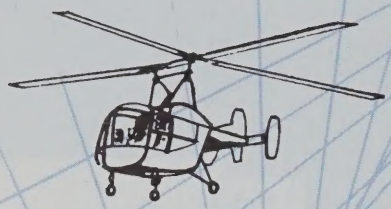
The NBS research effort is divided into several areas of investigation under the general supervision of Richard Reed, Chief of the Fracture and Deformation Division. The fracture mechanics group in Boulder, Colo., under Harry McHenry, uses crack opening displacement tests and crack driving force (J-integral) tests on surface-cracked panels to verify analytical models of fracture. This group also studies bend tests of small pre-cracked specimens to find the fracture toughness of base and weld metals. Work on sharp flaws gives information about effects of welding flaws such as lack of penetration and fusion. Results show that sharp flaws tend to be the most damaging for their size, because they concentrate stresses more than blunt flaws. In this group, Yi-Wen Cheng is responsible for verification of new models for analysis of sharp flaws. Chris Fortunko is working on a new ultrasonic system that uses long-wavelength shear horizontal waves for measuring flaw size, especially depth. The amplitude of the long-wave reflection can be correlated with flaw depth, and the shear horizontal mode eliminates many of the confusing spurious reflections seen with other modes. The system requires no coupling fluid between the pipe and the transducers, enabling its use at low temperatures and on unprepared surfaces.

In Gaithersburg, Roland DeWit is assessing existing and developing new analytical fracture mechanics models for surface flaws. James Early conducts tests of representative pipeline welds, measuring such material properties as fracture toughness, impact strength, yield strength, ultimate tensile strength, and fatigue crack growth rate at temperatures representative of the actual pipeline environment.

Another research area in Gaithersburg, under Harold Berger, has been developing new nondestructive methods for detecting and evaluating flaws and seeking to improve existing methods as well. As part of this program, Robert Placious has examined radiographic (x-ray) techniques, because existing x-ray methods provide accurate measurements of the length of a flaw parallel to the weld, but not of the through-wall depth of the flaw. He has found that more accurate depth measurements may be obtained by reducing the range of x-ray energy allowed, standardizing the film processing parameters, and improving the use of x-ray screens.

Yet another major area of research deals with the evaluation of the significance of real flaws in actual pipelines. Maurice Kasen in Boulder leads this effort, which includes fatigue tests of representative welds made under field conditions. Eventually, testing of full-scale pipeline sections will have to be conducted to include the effects of residual stresses found only in full-sized pipeline welds, and to assure that the fracture models developed and assessed using small specimens will properly scale up to full size. Some of these larger tests will be made at non-NBS facilities around the country.

The result of all these studies will be alternative weld acceptance criteria that will be established in advance for a given pipeline. The criteria can be adapted to other pipelines by the adjustment of material properties and operating stress factors. Welding repair and replacement costs can be lowered because certain flaws can be shown to have no effect on the safety of a given weld, even though that weld may not satisfy the usual workmanship standards. In addition, the new techniques evolved from this program may well allow inspectors to discover important flaws that escape notice in the traditional x-ray process. □



TESTING WITHOUT DESTRUCTION

Nondestructive Evaluation Techniques

by Harold Berger

HELICOPTER blades, welds in a nuclear pressure vessel, composite assemblies for airplanes, and cast aluminum automobile wheels—all have something in common. They are the types of critical components that require nondestructive evaluation (NDE). NDE represents a group of test methods that leave a tested object in a form useful for whatever original purpose was in mind for it. Under the right circumstances, NDE techniques can characterize an object as to defects (type, size, location, orientation) and materials parameters (grain size, texture and similar microstructural features, residual stress). That knowledge can be used to assess the serviceability of a component or structure and help to decide if it should be left in service, repaired, or replaced.

Safety has always been a major incentive for effective use of nondestructive evaluation. However, there are pressures on industry now to improve productivity and trade position, while giving attention to needs for material and energy conservation and product liability. Improved product quality ties in closely with these demands. NDE has a key role to play as industry moves toward improved quality.

Berger is Chief of the NBS Office of Nondestructive Evaluation.

NDE technology is advancing to meet expected needs for important decisions. At the present time, many would argue that NDE's measurements aren't sufficiently reproducible to be used as the basis for such crucial decisions. There is some evidence to support that view. However, some direct NDE measurements are now traceable to NBS; more are on the way.* It is our hope that these calibrations, Standard Reference Materials (SRM's), and improved procedures will lead to much better reproducibility of NDE measurements. This one step will lead to more reliable decisions about material serviceability.

NDE Methods

There are many techniques used for NDE. The six most widely used industrial NDE methods involve ultrasonics, radiography, eddy currents, visual-optical methods, liquid penetrants, and magnetic particles. The advantages and disadvantages of each are summarized in table 1. These techniques provide knowledge of a defect, such as slag in a weld, or the measurement of a material parameter, such as electrical conductivity, that is sometimes used to estimate the mechanical properties of aluminum alloys, for example.

Ultrasonic inspection, a rapidly expanding NDE technique, makes use of mechanical vibrations well above audio frequencies. The measurement procedures, mostly in the frequency range from a few hundred kHz to 15 MHz, involve amplitude, frequency, phase, velocity, and attenuation. The technique is used in reflection and through-transmission geometries and in a resonance mode. Ultrasonic testing is done with continuous vibrational energy applied (continuous wave) and with short pulses of energy. Most ultrasonic testing is done by a reflection technique, a sonar-like system, in which the primary measurement is the reflection amplitude of a pulse; a simple pulse echo system is shown in figure 1. The interface represented by a flaw would represent an acoustic impedance change and would result in a partial reflection of the ultrasonic signal. The time at which the pulse from the flaw is detected gives information about the flaw depth. The amplitude is often used as a measure of the size of the flaw.

Radiographic methods are generally more familiar because the industrial procedure is similar to the one used in medicine and dentistry. The object to be radiographed is placed between a radiographic

*D. C. Eitzen, H. Berger, and G. Birnbaum, "A Basis of Traceable NDE Measurements," Report NBSIR 80-2109, National Bureau of Standards (1980).

Table 1. Summary of Common Nondestructive Testing Methods

Method	Characteristics Detected	Advantages	Limitations	Examples of Use
Ultrasonics	Changes in acoustic impedance caused by cracks, nonbonds, inclusions, or interfaces.	Can penetrate thick materials; excellent for crack detection; can be automated.	Normally requires coupling either by contact to surface or immersion in a fluid such as water. Orientation can present problems in detection or interpretation of defect.	Adhesive assemblies for bond integrity. Detection of cracks.
Radiography	Changes in material density from voids, inclusions, material variations; placement of internal parts.	Can be used to inspect wide range of materials and thicknesses; versatile; film provides record of inspection.	Radiation safety requires precautions; expensive; detection of cracks can be difficult.	Pipeline welds for penetration, inclusions, voids. Verification of parts in assemblies.
Eddy Currents	Changes in electrical conductivity or magnetic permeability caused by material variations, cracks, voids, or inclusions.	Readily automated; moderate cost.	Limited to electrically conducting materials; limited penetration depth. Interpretation of defect signals can be difficult.	Heat exchanger tubes for wall thinning and cracks. Verification of strength of aluminum alloys.
Visual-Optical	Surface characteristics such as finish, scratches, cracks, or color; strain in transparent materials.	Often convenient; can be automated.	Can be applied only to surfaces, through surface openings, or to transparent material.	Paper, wood, or metal for surface finish and uniformity.
Liquid Penetrant	Surface openings due to cracks, porosity, seams, or folds.	Inexpensive, easy to use, readily portable, sensitive to small surface flaws.	Flaw must be open to surface. Not useful with porous material.	Turbine blades for surface cracks or porosity.
Magnetic Particles	Leakage magnetic flux caused by surface or near-surface cracks voids, inclusions, material, or geometry changes.	Inexpensive, sensitive both to surface and near-surface flaws.	Limited to ferromagnetic material; surface preparation and post-inspection demagnetization may be required.	Railroad wheels for cracks. Detection of weld defects.

detector, usually film, and a radiation source. Industrial radiography often encompasses a wider range of x-ray energies and sources than medical techniques. X-ray energies used for industrial inspection involve x-radiation of a few keV to many MeV. Industry makes use of radioisotopes such as iridium-192 and cobalt-60 because of their portability and relative freedom from power requirements. The common radiographic measurement involves differences in transmission intensity, usually represented by changes in film density (or darkening) on a radiograph (see figure 2). The radiographic image often provides much information about the size, type, and location of the defect.

A changing magnetic field near a conducting material will generate eddy currents in the material. The field generated by the eddy currents can be detected by a coil or other detector. The field will be perturbed by variations in the material because of discontinuities or changes in electrical conductivity or magnetic permeability. The measurements involve amplitude and phase of the magnetic field induced by the eddy currents.

The visual-optical method varies from straightforward visual observation to instrumented techniques that make use of magnifiers, borescopes, holographic equipment, or scanning optical systems. The measurements usually involve variation in reflected, transmitted, or diffracted intensity, polarization, or phase changes and/or color changes.

Similar optical observations are involved in both liquid penetrant and magnetic particle testing. For both of these methods, the inspector visually observes the configuration of particles or dyes on the surface of the inspected object. In the case of liquid penetrants, the process uses dye-containing liquids that enter surface-connected discontinuities after being placed on the part by dipping, brushing, or spraying. The excess liquid is removed from the surface. The liquid in the defect then is brought to the surface by the blotting action of a developer powder. This provides expanded indications with

high contrast (e.g., red penetrant on a white developer) or fluorescence (by use of an ultraviolet stimulated fluorescent dye in the penetrant) for easy visibility. Extremely small surface-connected defects can be detected by this simple technique. Crack widths on the order of a fraction of a micrometer are detectable under the proper conditions.

For example, a simulated-crack plate used to test the sensitivity of penetrant systems is shown in diagram form in figure 3. Thin-plated copper layers between thicker layers of nickel are etched to simulate a crack. Since the plated layer is uniform and its thickness can be accurately monitored, these simulated cracks have well-defined widths as small as 0.1 μm. Sensitive penetrant systems show even the narrowest crack.

These methods may present varying capabilities and apply to different kinds of materials, but the methods are complementary. A given part is often inspected by more than one NDE method. For example, a weld is usually examined visually to confirm fit and to detect surface problems such as undercut, lack of penetration, or arc burns. For certain steel welds, magnetic particle testing may be used to enhance detection of surface defects and to provide detection of some subsurface problems. Radiography and/or ultrasonic testing are often used to probe the interior of the weld for defects such as cracks, porosity, or slag. Two or more tests together provide much greater reliability than one test.

NDE Calibrations and Standards

Many services now performed by standards laboratories probably can be related to NDE. Checks

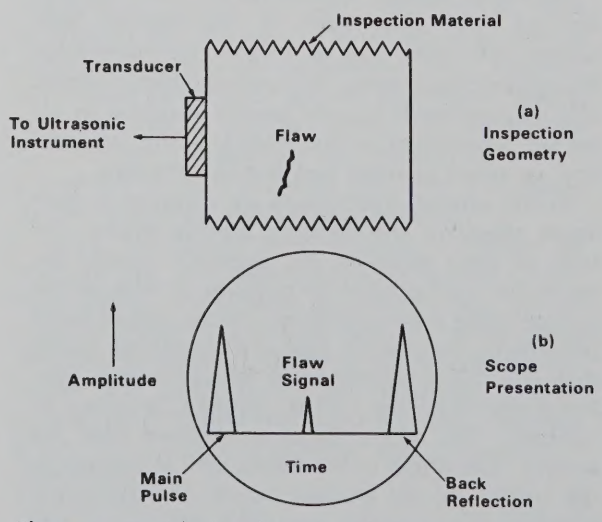


Figure 1—*Basics of pulse-echo ultrasonic NDE.*

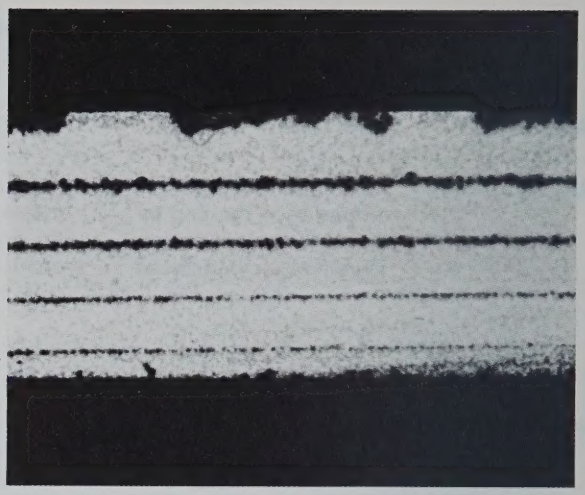


Figure 2—*Penetrant inspection of penetrant sensitivity crack plate; crack sizes are approximately 0.2, 1, 2 and 4 μm, top to bottom.*

Figure 3—*NBS scientist Robert Placious examines radiograph of pipeline weld.*

of voltage and frequency response for instrumentation used for NDE and calibration of radiation measuring equipment are examples. However, many additional measurement calibrations, more closely related to NDE measurement, are becoming available. Table 2 lists SRM's related to NDE that are available from NBS now or will be in the near future. NBS presently offers NDE calibration services in ultrasonic reference blocks, ultrasonic transducers; electrical conductivity calibrations will soon be available. These services are useful in providing better reproducibility and comparability of NDE measurements.

Let us illustrate how these work. One item in table 2 is an X-ray Film Step Tablet, a transparency containing 17 step shades of darkening over a density range from 0 to 4; estimated accuracy of the density measurement is 0.02 density units. This SRM can be used to provide traceability of radiographic film density measurements to NBS and would be most useful in the calibration laboratory for calibrating the densitometers or secondary density standards used in radiographic work. This type of traceability

would aid in providing compliance with a requirement for radiographs within a certain density range (a range from 1.5 to 3.5 is commonly specified). In important measurements for fracture mechanics analysis, where density variations are used to calculate the defect dimension through the material, the density measurements can be made traceable by use of this SRM.

Consider also the calibration of ultrasonic reference blocks, a service now available for aluminum and steel reference blocks (see figure 4). These reference blocks contain a flat bottom hole in one of the flat faces of the cylindrical block. The blocks are available with different diameter holes and different cylinder heights. A specification may require that an ultrasonic system be checked with a certain size block and that the reflection amplitude from the hole be noted. Products then tested with the system would be accepted if discontinuity signals were well below the noted reflection amplitude. Signals above a certain percentage (often 80 percent) of the reference block reflection amplitude would be cause for rejection or possibly further investigation. It is critical, therefore, that nominally identical reference blocks show similar ultrasonic response. Yet, it was found in an NBS study of aluminum reference blocks* prepared to an ASTM standard (ASTM E-127) that a typical variation of ultrasonic reflection amplitude for similar blocks was 40 percent. The effects of that startling variation can be much reduced if reference blocks are related to the NBS interim standard blocks by calibration. The calibration can be accomplished either by sending the user's blocks to NBS or by using a calibrated set of blocks borrowed from NBS so that the measurements can be made on the user's equipment.

Conclusions

Practical NDE measurements can be made traceable to national standards and, in the process, lead to improved measurement reproducibility. It is obviously of great importance that the NDE measurements made by the buyer relate closely to those made by the seller. Accurately calibrated NDE procedures will lead to greater reliance on the NDE results by both the manufacturer and the buyer.

It is of utmost importance that NDE measurements be reliable and repeatable, and this can happen only if NDE measurements systems can be calibrated accurately. A first step is the availability of traceable NDE measurement aids, both calibration services and Standard Reference Materials. The Nation's standards and calibrations laboratories now have tools to make NDE measurements traceable and, therefore, more reliable and reproducible.

The NBS Office of Nondestructive Evaluation is collaborating with standards and calibrations laboratories to help put NDE measurement procedures in place and welcomes suggestions for other NBS services and outputs that would improve these efforts. □

Table 2. Some NDE-Related SRM's

Now available	In progress
X-ray Film Step Tablet	Electrical Conductivity Standards
Coating Thickness Standards	Visual Acuity Test Chart
Metallo-organic Compounds for Wear Analysis	Fluorescent Brightness Comparison Standards
Mössbauer Standards	Radiographic Sensitivity Indicator
Penetrant Sensitivity Crack Plate	Calibrated Leaks
	Reference Samples for Wear Debris
	Residual Stress Standards

Figure 4—*An immersion tank is used by Donald Eitzen to measure responses of ultrasonic reference blocks.*

*G. F. Sushinsky, D. G. Eitzen and D. J. Chwirut, "Improved Ultrasonic Standard Reference Blocks," Report NBSIR 76-984, National Bureau of Standards (1976).

SPECIAL

by James F. Schooley

TWO years ago, the international Consultative Committee for Thermometry (CCT) took the first steps toward replacing the International Practical Temperature Scale (IPTS) of 1968. On June 17-19, 1980, the Committee met again in its 13th session to review the progress in thermometry research relevant to a new scale. It was concluded that a very long-lived scale could be constructed, provided that certain critical thermometry research efforts succeed.

In an earlier report, published in DIMENSIONS/NBS magazine,* we summarized the 1978 CCT meeting and sketched the history of the international temperature scales. The present report is intended to review the results of the 1980 CCT meeting so as to provide U.S. thermometrists and others with an update of progress toward a new IPTS.

In its procedures, the CCT is similar to the other six consultative committees. It meets periodically at the International Bureau of Weights and Measures in Sèvres, France, to review metrological questions and to recommend actions to the International Committee for Weights and Measures (CIPM). As with most consultative committees, attendance at the 1980 CCT meeting reflected national priorities and budgets. Among about 20 participants were representatives of the BIPM staff and thermometrists from the national laboratories of Australia, Canada, People's Republic of China, United Kingdom (UK), France, West Germany, East Germany, Italy, the Netherlands, and the United States. We were surprised to find no representatives from either Japan or the USSR; both of those countries have substantial thermometry research activities and normally send representatives.

Two Basic Questions

Very basic questions concerning the most useful roles for the CCT and the IPTS were discussed during the sessions. Among those questions were two that are asked frequently of the NBS by concerned U.S. scientists: 1) Why should we replace the IPTS-68? and 2) What can the CCT do for the so-called "secondary laboratories" which do not require the most accurate level of thermometry?

Similar questions, it seems, are asked in most of the other CCT member countries, so that the Committee was determined to measure the effectiveness of any new scale in terms of its practical advantages and the needs of secondary as well as primary laboratories.

On the advantages of a new IPTS, the CCT members noted several features of current research in thermometry:

—It now appears that an IPTS could be used to assign values to indefinitely low temperatures as well as to indefinitely high ones.

—Very considerable (at least a factor of 10) improvement in reproducibility over the IPTS-68 is expected for the range 630 °C to 1064 °C.

—Considerable enhancement of the "practicality" of the IPTS may be introduced by use of sealed, transportable temperature reference cells, and further, by the simplification of the platinum resistance thermometry equations.

—Measurements of thermodynamic temperatures from below 1 K to above 1000 K are in progress in laboratories throughout the world.

These features provide the possibility of replacing the IPTS-68 with a scale that extends to both very high and very low temperatures, that offers relatively convenient, state-of-the-art precision throughout its range, and that agrees closely with thermodynamic temperature determinations.

There was a strong consensus within the CCT that, although a rough "timetable" for replacing the IPTS-68 was set in 1978 to guide the work of the Committee, it is eventually the progress of the many current research projects that must determine the timing for introduction of a new scale.

The CCT took positive steps to provide guidance to secondary thermometry laboratories to assist them in their work. One of the four Working Groups established during the meeting was assigned the task of creating documents to assist in secondary realizations of the IPTS. One such document will update the recent cataloging of secondary reference points; it will feature, in addition to an up-to-date listing of temperature values, a classification of the individual measurements according to the level of experimental uncertainty and, where available, data on sample purity. Perhaps more important to secondary laboratories is the task of another Working Group (II)—documentation of secondary thermometer measurement techniques.

The first effort in this direction was proposed for thermocouple thermometers. The Committee re-

Schooley, Chief of the NBS Temperature and Pressure Measurements and Standards Division, was the NBS delegate to the 13th CCT meeting.

**Dimensions/NBS, September 1978, pp. 20-25.*

quested that Working Group II recommend particular thermocouple types for specific ranges of temperature, designate reference tables for their use, and provide instructions for thermocouple thermometry. Existing information will be collected in one reference and recommendations provided for the choice and measurement procedures in thermocouple thermometry. These are expected to be of considerable assistance to secondary laboratories. However, the CCT noted that the higher precision of high-temperature platinum resistance thermometers (PRT) is likely to result in the future elimination of the thermocouple thermometer from the IPTS itself.

At a future time, the CCT contemplated that Working Group II (or its successor) might perform similar services with respect to secondary resistance thermometers and perhaps other secondary thermometers.

Agenda for the CCT Meeting

The CCT faced a very full agenda for its 13th meeting. Several questions remained from the previous meeting in 1978, and it was necessary to consider reports submitted from each of the five Working Groups operating during the intervening period. In addition, some 68 information documents were submitted to the CCT, principally from staff thermometrists of its member laboratories. The CCT timetable for replacing the IPTS-68 (outlined at its 12th meeting in 1978) called for a discussion of the principles of a new scale; this discussion was to be followed by a determination of the composition and responsibilities of new Working Groups assigned to monitor and encourage crucial projects. A further question for consideration concerned the desirability of submitting proposals to the International Committee for Weights and Measures. A final agenda item called attention to the 6th Temperature Symposium, scheduled for March 1982 in Washington, DC, just prior to the time proposed for the 14th CCT meeting.

The Committee was able to complete discussion of all agenda items within the allotted three days. This reflected in part the careful preparation of the participants (the agenda, 50 of the 68 submitted documents, and four of the five Working Group reports were available for study before the meeting) and in part to the discipline and planning of the president of the meeting, H. Preston-Thomas of the National Research Council, Ottawa, Canada.

We can not summarize here all the information available to the CCT and the discussions that led to the broad conclusions already mentioned. However, it may be helpful to call attention to some of the more significant details that led to these conclusions. These items can be categorized roughly under the headings of temperature reference points, thermodynamic measurements, and standard thermometers.

Temperature Reference Points

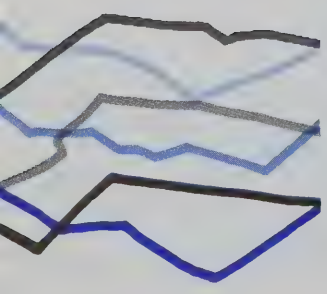
NBS temperature specialists have realized for some time that the current economic inflation might play a determining role in the selection of fixed points for a new temperature scale. Used in the standard fashion, the gold in a freezing-point device

Progress Toward A New Scale of Temperature

is now worth as much as $100,000. This raises the question of whether the gold freezing point device is "practical" any longer. Of two alternatives (to use less gold in a new type of fixed-point device or to work towards a less expensive alternative material), the CCT discussions centered on the possible use of the copper freezing point as either a replacement for or an alternative to the gold freezing point. Several contributed papers from other national laboratories noted that the copper freezing point—only 20 °C higher than the gold freezing point—can yield a thermometric imprecision of less than ±0.01 °C if some care is taken to avoid oxidation, and, therefore, the copper point can be considered to be a realistic alternative to the gold point for scale definition.

Considering the very high temperature precision possible with gallium and mercury triple-point cells (see figures 1 and 2) and the observation that, of all currently-used temperature fixed-point substances, the water/ice/water-vapor system shows the slowest thermal response, CCT representatives considered the possibility of prescribing the use of the metal points in determinations of the alpha coefficient of standard platinum resistance thermometers. This step, however, would bring the definition of the kelvin into question.

On the day before the CCT meeting, representatives of eight laboratories participating in an intercomparison of sealed triple-point cells met at the BIPM. The intercomparison, led by the Istituto di Metrologia "G. Colonnetti" (IMGC) (Italy) under the auspices of the CCT, involved measurements with hydrogen, neon, oxygen, argon, and methane (respective nominal triple-point temperatures of 14 K, 24 K, 54 K, 84 K, and 90 K). In his verbal report, Pavese of IMGC noted that he could comment on the precision of this type of device only in the case of argon, since relatively few other measurements are complete. For argon, however, a limiting imprecision of ±0.2 mK has been reached. Important attributes of the sealed-cell fixed-point method that were noted by the CCT are that such an intercomparison permits, in addition to an evaluation of the devices themselves, a comparison of the local temperature scales of the participating laboratories as well as the derivation of an IPTS-68 "best value" of the triple-point temperature for each substance studied.



Noting the substantial gap in temperature between the triple-point temperature of argon (84 K) and that of mercury (235 K), several members suggested that Kr (t.p. temperature 116 K) and perhaps isotopically enriched Xe (t.p. 160 K) be investigated to provide fixed points in a region where the PRT resistance-temperature relation is somewhat variable.

There was a strong consensus within the CCT that, if possible, boiling points should be abandoned as defining points in any new scale. The relative convenience of the use of metal freezing points, sealed triple-point cells, and superconductive transition points makes them far more attractive than boiling points for defining a "practical" scale. One exception to this rule is the possible retention of the 3-He and 4-He boiling points as fixed points in conjunction with helium vapor-pressure thermometry, since in this case the pressure measuring apparatus would already be in place.

The CCT noted that temperature fixed-points are likely to be needed near 7 K and 9 K, particularly if temperatures in that range are to be defined in terms of resistance thermometry. Although Pb and Nb, respectively, undergo superconductive transitions near those temperatures, in neither case can temperatures now be defined as precisely as ±0.2 mK. Thus, the CCT was moved to recommend officially to the CIPM that research on these points be intensified.

Although Soulen at the NBS has prepared fixed-point devices (known as the NBS SRM 768 devices) that provide individual superconductive reference temperatures with imprecision levels of ±0.1 mK at five temperatures between 0.3 K and 0.01 K, the transition temperatures are not identical for all samples. As a result, the CCT Working Group was hesitant to recommend that these devices be used to provide defining points for the new scale.

Thermodynamic Measurements of Temperature

Workers at several laboratories have examined the thermodynamic consistency of the IPTS-68 between 630 °C and 1085 °C, using the methods of radiometric thermometry. A strong discrepancy between Planck-law temperatures and the IPTS-68 (as much as 0.5 °C near 800 °C) has appeared in each of these experiments (see data above 500 °C in figure 3). In any replacement for the IPTS-68, this "bulge" clearly must be removed.

Between 0 °C and 450 °C, the NBS gas thermometry experiment has provided very precise measurements of a smaller discrepancy in the opposite direction. The relation between thermodynamic temperature as derived from the gas thermometer

and the IPTS-68 is given by the equation

$$T(K) - T_{68}(K) = \frac{-120887.784}{T_{68}^2} + \frac{1213.53295}{T_{68}} - 4.3159552 + 0.00644075647\,T_{68} - 3.56638846\times10^{-6}\,T_{68}^2$$

The graph of this relation is plotted in figure 3; at 450 °C, it shows a temperature difference of 0.08 °C between the IPTS-68 and the thermodynamic temperature.

A new gas-thermometer bulb, able to withstand temperatures as high as 1100 °C, has been constructed for the NBS experiment, and new measurements above 450 °C are in progress.

Measurements of thermodynamic temperature below 0 °C have been made in several laboratories, mostly on the basis of gas thermometry or noise thermometry. The level of agreement of values among these experiments is substantially better than has existed heretofore. The Working Group IV report contains an estimate of accuracy stated as 3 mK at 90 K and 1 mK or less below 20 K. By using the new transportable low-temperature reference points, the various contributing laboratories can reproduce fixed-point temperatures with virtually no loss of accuracy. The lowest-temperature research on thermodynamic temperatures reported to the CCT was that of Marshak and Soulen at the NBS. Using gamma-ray anisotropy and noise temperature measurements, they have assigned thermodynamic temperatures to superconducting fixed points and to stable resistance thermometers. In this way they have created a temperature scale in the range of 0.01 K to 0.52 K, referred to as NBS-CTS-1.

Standard Thermometers

The IPTS-68 does not recommend a standard thermometer for use at temperatures above 1337 K, the freezing point of gold. Rather, it prescribes the use of the Planck Law of radiation

$$\frac{L_\lambda(T_{68})}{L_\lambda(1337.58)} = \frac{\exp(c_2/1337.58\lambda) - 1}{\exp(c_2/T_{68}\lambda) - 1}$$

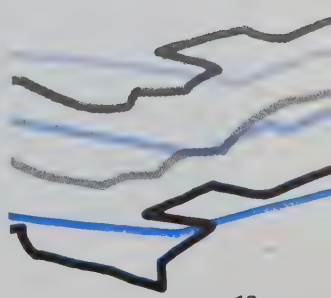
in which L_λ represents the spectral concentration of the radiance of a blackbody at the wavelength for the respective temperatures and $c_2 = 0.014388$ m·K.

For most realizations of the IPTS-68 above the gold point, photoelectric optical pyrometers are used, with monochromatic filters to provide a narrow band of wavelength and photomultiplier (or photodiode) detectors. No change is envisioned for the definition of temperature in the Planck Law range. It is quite possible, however, that the base temperature for radiation thermometry might be changed from the gold freezing point to the copper freezing point as noted in the previous section, or, on the other hand, lowered to the silver freezing point.

The uncertainty of the platinum-10% rhodium vs. platinum thermocouple thermometer in measuring temperatures on the IPTS-68 amounts to 0.2 °C or more from 630 °C to 1064 °C. This large uncertainty has stimulated a number of laboratories to try to improve the high-temperature performance of platinum resistance thermometers over the past decade or so. Currently, the work of Evans at NBS has shown that 2.5-ohm nominal resistance thermometers incorporating only platinum wire and fused silica can be used at temperatures as high as 1100 °C. The final design of the thermometer has not been settled, but the results to date indicate that the new thermometers can attain one-tenth or less of the level of thermometric imprecision at the gold point now obtained using the platinum-10% rhodium vs. platinum thermocouple thermometer. If these preliminary measurements are borne out by similar experience with the new resistance thermometers in other major thermometry laboratories, the thermocouple thermometer will certainly be omitted from the new temperature scale. The highest temperature for which the new thermometers define a new scale, however, will depend upon factors such as their lifetime and reproducibility at high temperature and the simplicity of expressing the resistance-temperature relation.

Staff members of several CCT member laboratories are planning to participate in the high-temperature studies at the NBS, including representatives from Italy, W. Germany, Canada, and Australia.

In the range of temperature below 14 K, no thermometer has yet appeared to be clearly superior as a standard interpolating instrument. Several different types are under study, including resistance thermometers, gas thermometers, and paramagnetic thermometers. It is possible that more than one type will be needed to span the extended IPTS range of temperature.



Recommendations and Working Groups of the CCT

On the basis of the foregoing and other information, the CCT concluded that it is quite reasonable to consider replacing the IPTS-68, since a replacement scale can incorporate very definite improvements in extent, accuracy, and precision, as well as provide more "practicality." The major changes are summarized in table 1.

The CCT noted that several research projects are crucial to the formation of a replacement scale. The Committee responded to this situation in two ways—first, by recommending to the CIPM that its member laboratories stress these areas during the coming months, and second, by establishing Working Groups to monitor progress in the experiments. Table 2 lists the recommendations to the CIPM.

During the coming 2-year period, the four Working Groups of the CCT will coordinate the experimental results of contributing laboratories and help to elicit the "first try" at a new temperature scale formulation.

The fact that the 6th Symposium on "Temperature—Its Measurement and Control in Science and Industry" will take place in March 1982 was noted at the CCT meeting. This Symposium will be the latest in a series that has occurred at roughly 10-year intervals since 1920. Sponsored by the National Bureau of Standards, the American Institute of Physics, and the Instrument Society of America, the symposium program will feature talks on advances in fundamental thermometry at the beginning of each day's session. The CCT considers the Symposium a good opportunity for the leading researchers in thermometry to discuss possible tem-

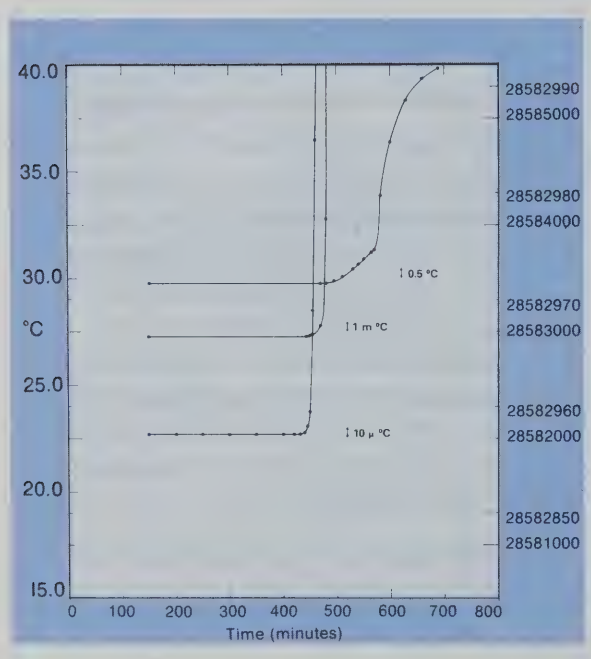


Figure 1—*The triple-point melting curve of a very pure gallium sample. The curve is shown three times, with increasing magnification of the temperature axis, to portray the temperature uniformity of the first 5-hour portion. The left-hand scale refers to the upper curve, observable with modest* **(tenth-degree)** *temperature resolution. The resistance scale from 28581000 to 28585000 accompanies the middle curve, showing data observable with* **tenth-millidegree** *temperature resolution. Finally, the lower curve, corresponding to the resistance scale from 28582950 to 28582990, shows the data taken with a temperature resolution of about* **2 microdegrees**. *Reprinted from "Determination of the Triple-Point Temperature of Gallium" by B. W. Mangum and D. D. Thornton,* **Metrologia 15:** *201-215 (1979), with the authors' permission.*

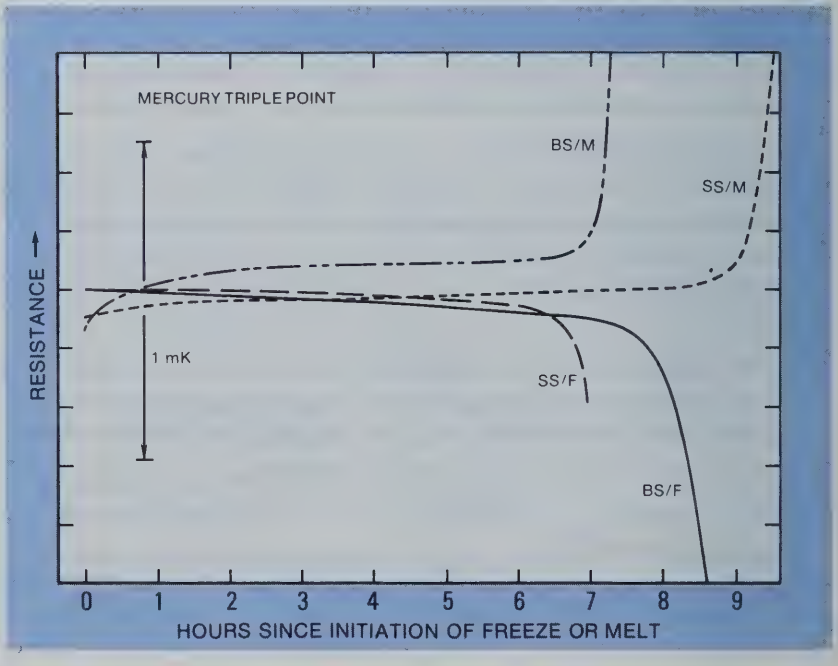


Figure 2—*Triple-point freezing and melting curves obtained with mercury samples in borosilicate glass cells (curves marked BS/F and BS/M, respectively) and in stainless steel cells SS/F and SS/M, respectively. The change in thermometer resistance equivalent to 1 mK in temperature is indicated by a vertical line. Figure taken, with the authors' permission, from "Applications of Some Metal SRM's as Thermometric Fixed Points" by G. T. Furukawa et al., to be published as an NBS Special Publication.*

perature scale changes in considerable detail. The next meeting of the CCT was tentatively scheduled for 1982, within a month after the close of the 6th Temperature Symposium.

NOTE: We particularly point out that this report is based upon personal notes made by the author during the meeting. The official minutes of the 13th CCT Meeting will be published by the International Bureau of Weights and Measures (BIPM). Copies of those minutes (in French, the official language) may be obtained from the BIPM in Sèvres, France.

Details of current NBS research projects and references to published papers on topics discussed in this report can be obtained by writing J. F. Schooley, B128 Physics Building, National Bureau of Standards, Washington, DC 20234. □

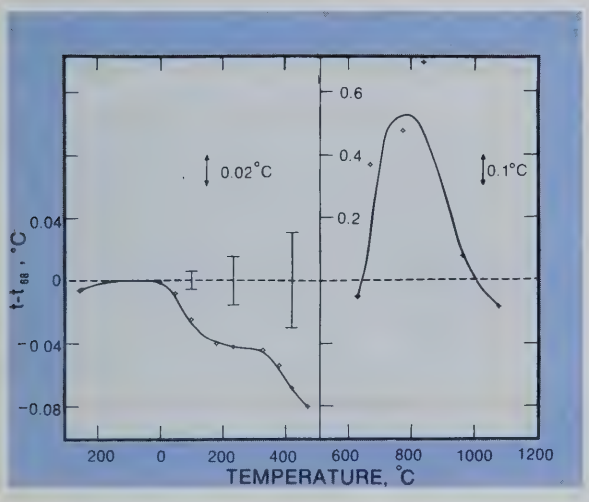


Figure 3—*Differences between Celsius thermodynamic temperatures (t) and the International Practical Temperature Scale of 1968 (t_{68}), as indicated by current thermometry research discussed in the text. Note that the equation in the text uses temperature in kelvins, T(K) and the graph uses temperature in degrees Celsius, t. The estimated thermodynamic uncertainty levels of the IPTS-68 are indicated at 100 °C, 232 °C, and 420 °C (from table 7,* **Metrologia 5:** *35-44, 1969). Also note the change of vertical scale at 500 °C. (Reprinted from September 1978 DIMENSIONS/NBS).*

Table 1 **Possible Changes in the International Practical Temperature Scale and Their Consequences**

1. **Temperature Reference Points.** Eliminate boiling points from the scale definition. Retain metal freezing points. Introduce sealed triple-point cells and superconductive transitions. Results—all temperature reference points can be transported from laboratory to laboratory; the scale can be extended substantially below 13.8 K.
2. **Standard Thermometers.** Eliminate thermocouple thermometers as defining instruments from 630 °C to 1064 °C and replace with new platinum resistance thermometry. Introduce the gas thermometer or a resistance thermometer below the platinum resistance thermometry range. Introduce helium vapor-pressure thermometry or paramagnetic thermometry below 4 K. Results—temperature scale precision between 630 °C and 1064 °C improved by a factor of ten or more; definition of scale temperatures can be extended to nearly indefinitely low values.
3. **Interpolation Equations.** Remove discrepancies with respect to thermodynamic temperatures. Simplify the low-temperature platinum resistance thermometry formulation. Extend the platinum resistance thermometer equations to a new upper limit. Provide equations for any new low-temperature standard thermometers. Results—thermodynamic accuracy of new scale improved by as much as 0.5 °C; easier temperature measurements and calculations.

Table 2 **Recommendations of the Consultative Committee on Thermometry**

- Work on the measurement of thermodynamic temperatures should be intensified, particularly in the temperature ranges 14 K to 90 K and 0 °C to 1100 °C.
- Work should be intensified on the construction, characterization, and international intercomparison of high-temperature platinum resistance thermometers for the range up to 1100 °C.
- Research should be carried out to ensure the precision of any future scale and its smoothness with respect to thermodynamic temperatures.
- Appropriate research should be carried out, especially considering superconductive transitions, to produce well-defined reference temperatures between 4 K and 14 K.

NEW RAMAN MICROPROBE WITH MULTICHANNEL OPTICAL DETECTOR

by Edgar S. Etz

The Center for Analytical Chemistry of the National Bureau of Standards, in collaboration with Instruments SA, Inc. of Metuchen, New Jersey, has been exploring the advantages of a new prototype Raman microprobe with multichannel optical detection.

Other Raman microprobes that have come into use in recent years employ a laser beam for excitation of the Raman spectrum, but basically they make use of a scanning spectrometer (i.e., a monochromator) with conventional single channel, cooled photomultiplier tube (PMT) detection. These instruments yield analytically useful vibrational spectra from discrete microscopic objects (e.g., particles) or sample regions with dimensions of a few micrometers (e.g., inclusions). They have been applied with good success in the chemical characterization of many types of samples demonstrating detection limits lower than 1 picogram (10^{-12} g) for scattering species in optically transparent sampling volumes.* However, microanalysis performed with these scanning instruments suffers from several shortcomings which result primarily from two factors. These factors are: (1) the long instrumentally-imposed time (tens of minutes to hours) required to obtain a spectrum with monochannel detection; and (2) the often severe optical constraints on the measurement encountered whenever the sample absorbs a fraction of the incident (visible) laser light, usually leading to complications from sample heating or photochemistry. These problems can, in principle, be minimized or circumvented by microprobe instrumentation employing spectrographic dispersion with sensitive multichannel detection.

The new instrument (figure 1) embodying these characteristics has just become fully operational and is presently undergoing extensive performance characterization. Results obtained with this instrument demonstrate the spectral multiplex advantage in the analysis of "difficult" (e.g., optically absorbing, photosensitive, or generally unstable) microsamples.

This development has utilized commercially available equipment consisting of two gas lasers (Ar and Kr ion) as multi-wavelength excitation sources, a standard microscope for observation of the sample and excitation/collection of the scattered radiation, a triple spectrograph of novel design for dispersion of the Raman spectrum, and a multichannel detection system utilizing a cooled silicon intensified target (SIT) vidicon array detector. A separate, auxiliary detection system consists of a conventional photomultiplier tube (PMT) with photon counting electronics and permits scanning or spectrometric recording of spectra at higher (spectral) resolution.

A result from the measurement on single microparticles is shown in figure 2. The sample examined here is a microscopically small polymer latex particle. Some of the experimental parameters are indicated in the figure caption. The spectrum was acquired in the multichannel mode of operation, requiring only three minutes of signal integration. This represents a time advantage in the acquisition of the spectral "finger-print" by a factor of about 18 compared to the corresponding spectrum (of comparable signal-to-noise) obtained in a conventional microprobe with a scanning spectrometer. Moreover, since the polymer is subject to time-dependent slow decomposition, even under conditions of moderate laser irradiance, these potentially adverse effects are not apparent in this example.

The instrument was developed with support from the Air Force Technical Applications Center (AFTAC) and is now in use at an Air Force materials analysis laboratory on the West Coast.

Etz is a staff member of the Microanalysis Group in the Center for Analytical Chemistry. The research reported here was conducted jointly with Captain Wayne R. Steinbach (USAF) of the McClellan Central Laboratory, McClellan AFB, California. Collaborators in this instrument development were Frances Adar and Donald Landon, both of Instruments SA.

*E. S. Etz and J. J. Blaha, Scope and Limitations of Single Particle Analysis by Raman Microprobe Spectroscopy, in *Characterization of Particles*. NBS Spec. Publ. 533, ed. K. F. J. Heinrich, U.S. Government Printing Office, Washington, DC (1980), pp. 153-197.

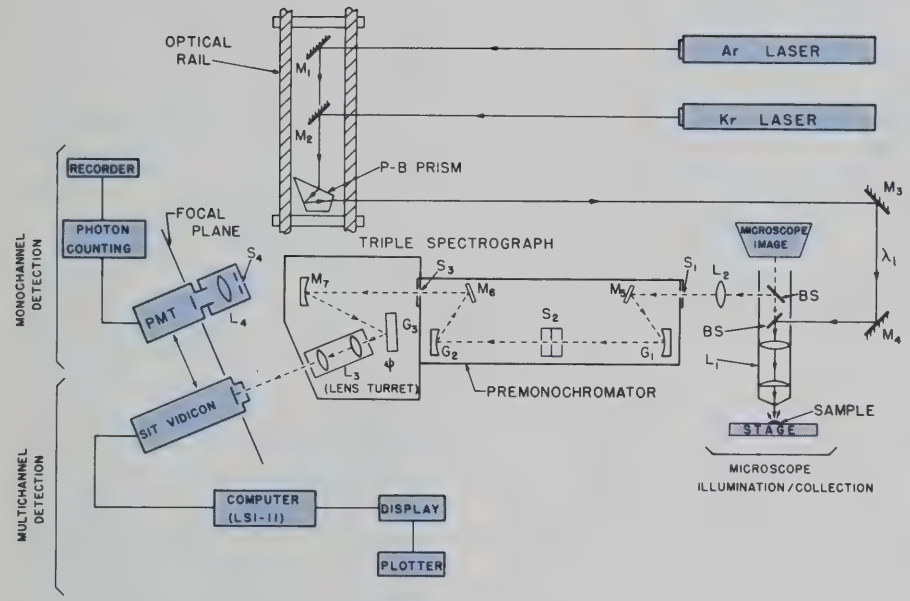


Figure 1—*Schematic of the newly developed Raman microprobe showing principal components of the instrument layout.*

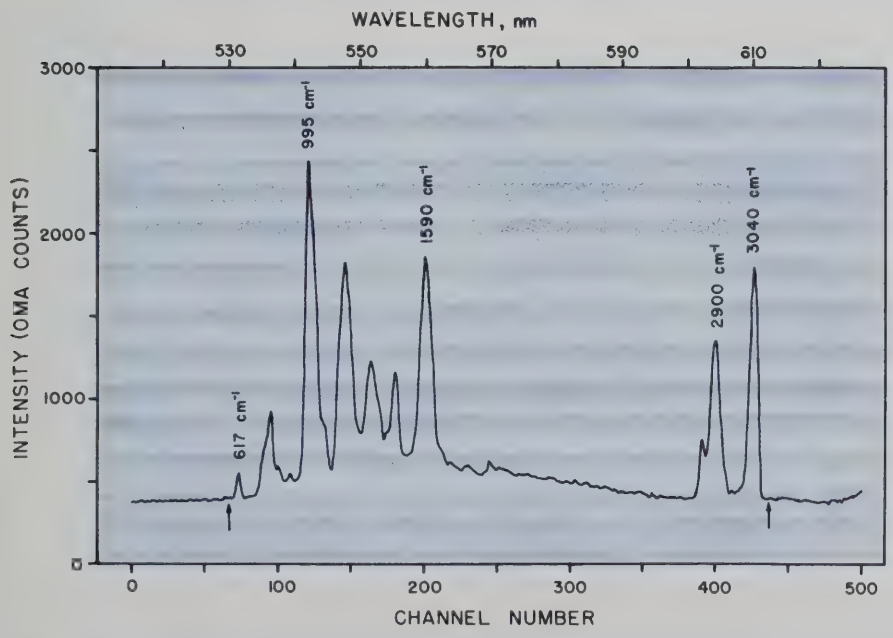


Figure 2—*Raman spectrum of a polystyrene latex microsphere (~15 μm in diameter) obtained with multichannel detection. The particle is supported by a sapphire (α-Al_2O_3) substrate. Laser excitation 514.5 nm (green line) radiation, at a power of 12 mW, is focused into a beam spot (~8 μm in diameter) at the sample. Spectral coverage is nearly 2500 cm^{-1} simultaneously obtained in 3 minutes of signal acquisition time.*

KINETIC DATA BASE FOR ATMOSPHERIC CHEMISTRY

by Robert F. Hampson

A report* just issued provides a critically evaluated chemical kinetic data base for calculations modeling atmospheric chemistry. This report, entitled "Chemical Kinetic and Photochemical Data Sheets for Atmospheric Reactions," was prepared by Robert F. Hampson, Chemical Kinetics Division, NBS Center for Thermodynamics and Molecular Science.

It presents a set of individual data sheets for gas phase chemical reactions and photochemistry of neutral species. These data sheets give preferred values for reaction rate constants, photoabsorption cross-sections, and quantum yields, with a brief statement discussing the basis for the preferred value. Recent experimental results are also given.

The coverage of the data sheets included in this publication corresponds to the approximately 450 reactions which were considered either in NBS Special Publication 513, May 1978, or in the 1979 evaluations of the NASA Panel for Data Evaluation or the CODATA** Task Group on Chemical Kinetics. These data sheets are intended to provide the basic physical chemical data needed as input for calculations modeling atmospheric chemistry.

This work was supported, in part, by the FAA High Altitude Pollution Program of the Office of Energy and Environment and the Upper Atmosphere Research Office of the National Aeronautics and Space Administration. It was also supported by the Office of Standard Reference Data of the National Bureau of Standards.

The CODATA Task Group on Chemical Kinetics has prepared an evaluated data base on chemical reactions that occur in the atmosphere. This data base emphasizes those reactions relating to ozone depletion in the stratosphere and is intended to provide the basic data needed for atmospheric chemistry models in this regard.

The evaluation is presented in the form of 148 detailed data sheets for thermal and photochemical reactions. Each sheet contains summaries of the available experimental data and comments on experimental procedures. For each reaction, a preferred value of the rate coefficient at 298 K is given, together with a temperature dependence where possible. In addition, the selections of the preferred data are discussed, and estimates of their accuracy are given. The evaluation appears in the *Journal of Physical and Chemical Reference Data 9*, 295–471 (1980).

For further information contact Robert F. Hampson, Chemical Kinetics Data Center, National Bureau of Standards, Washington, DC 20234; phone 301/921-2565.

Hampson is director of the Chemical Kinetics Data Center.

*Report No. FAAEE-80-17, Dept. of Transportation, FAA, Office of Environment and Energy, Washington, D.C. 20591.

**Committee on Data for Science and Technology of the International Council of Scientific Unions.

Chemical Kinetics Data Survey

Prepared at Chemical Kinetics Data Center, National Bureau of Standards

No. (Code)	Reaction/Reference	Temp. Range/K	Reaction Rate Constant k/cm^3 molecule^{-1} s^{-1}	Uncert. Factor at 298 K; notes
1, 1M	$0 + 0 + M \rightarrow 0_2 + M$		H(298) = −498 kJ/mol	
	Campbell, Gray (1973)	200-300	$4.8 \times 10^{-33} (T/300)^{-2}$; M = N_2	1.3
	Baulch et al. (1976) rev.	190-4000	$5.2 \times 10^{-35} \exp(900/T)$; M = Ar	1.3
	Johnston (1968) review	1000-8000	$3.80 \times 10^{-30} T^{-1} \exp(-170/T)$; M = 0_2	
	Taylor (1975) review	2000-10000	$1.7 \times 10^{-32} T^{-1/2}$; M = N_2	
			$2.2 \times 10^{-28} T^{-3/2}$; M = 0_2	
			$6.2 \times 10^{-28} T^{-3/2}$; M = 0	
			$8.3 \times 10^{-33} T^{-1/2}$; M = N, NO	

This evaluation accepts the results of Campbell and Gray (1973) at low temperature and with M = N_2 as most applicable to stratospheric chemistry, and also accepts the recent recommendation of Baulch et al. (1976) for an extended temperature range with M = Ar.

References

Baulch, D.L., Drysdale, D.D., Duxbury, J., and Grant, S.J., "Evaluated Kinetic Data for High Temperature Reactions, Vol. 3: Homogeneous Gas Phase Reactions of the $0_2 - 0_3$ System, the $CO - H_2$ System, and of Sulphur-Containing Species," (Butterworths, London, 1976).

Campbell, I.M., and Gray, C.N., "Rate Constants for 0(^{3}P) Recombination and Association with N(^{4}S)," Chem. Phys. Lett. *18*, 607-609 (1973).

Johnston, H.S., "Gas Phase Reaction Kinetics of Neutral Oxygen Species," NBS-NSRDS-20, 1968. (Supt. of Documents, U.S. Govt. Printing Office, Washington, D.C. 20402.)

Taylor, R.L., "High Temperature Reactions of Air," pp. 5-154 to 5-157 in "The Natural Stratosphere of 1974" Climatic Impact Assessment Program, Monograph 1, DOT-TST-75-51, Department of Transportation, Washington, D.C., September 1975.

R.F. Hampson
May 1978

Chemical Kinetics Data Survey

Prepared at Chemical Kinetics Data Center, National Bureau of Standards

No. (Code)	Reaction/Reference	Temp. Range/K	Reaction Rate Constant k/cm^3 molecule^{-1} s^{-1}	Uncert. Factor at 298 K; notes
9, 20	$NO + HO_2 \rightarrow NO_2 + HO$		ΔH (298) = − 20 kJ/mol	
	NASA (1979) eval	200-300	$4.3 \times 10^{-12} \exp((200 \pm 200)/T)$	1.2
	CODATA (1979) eval	230-425	$4.3 \times 10^{-12} \exp((200 \pm 200)/T)$	1.2
	Zahniser, Howard (1978)	230-400	$3.3 \times 10^{-12} \exp(254/T)$	
	Leu (1979)	270-425	$5.7 \times 10^{-12} \exp(130/T)$	
	Margitan, Anderson (1978)	298	8.0×10^{-12}	
	Kaufman, Reimann (1978)	298	7.9×10^{-12}	
	Burrows et al. (1978)	298	8.2×10^{-12}	
	Howard, Evenson (1977)	296	$(8.1 \pm 1.5) \times 10^{-12}$	
	Hack et al. (1975)	298-670	$2.0 \times 10^{-11} \exp(-1200/T)$	
	Simonaitis, Heicklen (1977)	245-328	$k/(k_{ref})^{0.5} = 6.4 \times 10^{-6} \exp(-700/T)$ (a)	
	Cox, Derwent (1975)	296	1.2×10^{-12}	
	Payne, Stief, Davis (1973)	300	3×10^{-13}	
	Glanzer, Troe (1975)	1350-1700	7.5×10^{-12}	

(a) Reference reaction: $2HO_2 \rightarrow H_2O_2 + O_2$

The recommendation is based on Zahniser and Howard (1978) and Leu (1979), the room temperature determinations of Margitan and Anderson (1978) and Kaufman and Reiman (1978), and the ratio determination by Burrows et al. (1978) relative to $OH + H_2O_2$. The agreement is excellent.

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R.F. Hampson
June 1979

STAFF REPORTS

BREAKDOWN BETWEEN BARE ELECTRODES WITH AN OIL-PAPER INTERFACE

The Electrosystems Division of NBS has carried out experiments to pinpoint the location of electrical breakdown in a composite insulating system. The materials chosen for study were paper and oil, a typical combination in use today. For these measurements, a paper specimen was mounted so that it connected two stainless-steel electrodes, the whole being immersed in the oil. Electrode geometries used included plane-plane and sphere-sphere. The data gained from these experiments indicate that if the materials are prepared in accordance with current industrial practice (for example, if the paper is carefully dried), breakdown will not necessarily occur at the interface as had heretofore been assumed. These results are expected to provide new insights for the testing and design of insulating systems and to contribute to an improved understanding of breakdown phenomena.

Edward F. Kelley and Robert E. Hebner, Jr., Electrosystems Division, B344 Metrology Building, 301/921-3121.

A current trend in high-voltage technology is to increase the energy density in high-voltage apparatus and systems. This trend is seen in applications ranging from the transmission and distribution of electric power to the development of fusion energy sources. In power systems, for example, environmental and esthetic concerns, coupled with the increasing cost and decreasing availability of open land, provide a strong incentive to maximize the electric power that can be transmitted safely and reliably in existing rights-of-way. These societal pressures lead the system builder to reduce traditional overdesign margins. A further complication is that material shortages may require the builder to introduce materials not proven in long service in a way that is expected to avoid a significant decrease in either reliability or energy density.

The maximum safe operating voltage of electric equipment is determined in large part by the performance of insulating systems. These systems are composites, such as paper-oil or gas-ceramic, in order to meet the requirements of practical apparatus. For instance, in compressed-gas-insulated transmission lines, power supplies, or measuring systems, it is necessary to use a solid spacer to provide mechanical support for the high-voltage conductor (in one common arrangement, a central high-voltage conductor is surrounded by a hollow cylindrical conductor at low voltage or ground). In such cases, the breakdown strength of the system has been presumed to be determined by the electrical behavior of the gas-solid interface which is at the surface of the support. Similarly, in oil-insulated apparatus, paper or pressboard is used both as a spacer and to improve the dielectric behavior of the system. Again, it has been assumed that the most susceptible sites for breakdown are at the oil-paper interface.

Much of the modern work on interfacial breakdown has been influenced by the results of Wechsler and Riccitiello.* Their work showed that a test method then widely used for solid insulators was inadequate. The test consisted of inserting probe electrodes through the solid specimen in a manner so as to have a known separation between them, immersing this assembly in oil, and recording the breakdown voltage. The researchers concluded that the test was not suitable for determining volume breakdown properties of the solid specimen because it was observed that breakdown usually took place at or near the liquid-solid interface.

Recognizing that there were measurement constraints to predicting and controlling dielectric interfacial phenomena, and the practical implications of a better understanding of these phenomena, the Office of Electric Energy Systems of the Department of Energy has funded an experimental investigation at the National Bureau of Standards. The objectives of this work have been to (1) develop techniques to measure the electric field distribution and the space charge density in materials used in electric power equipment and systems, (2) understand the interfacial processes in specific insulation systems, and (3) demonstrate the applicability of the measurement techniques to practical systems involving liquid-solid, gas-solid, and extruded dielectrics.

The NBS experimental approach combines state-of-the-art electrical measurements, a fluid-handling system that permits accurate characterization of the fluid under test, and advanced photographic techniques to record the location of each breakdown. The photographic capability has proven to be particularly important in determining whether or not breakdown occurs at the interface, because the shock wave generated by breakdown near the interface almost always tears the paper insulator, which is positioned to connect the two electrodes. If electrical measurements and post-breakdown visual examination of the interface were the only available analysis tools, the damage would likely be incorrectly interpreted as evidence of interfacial breakdown.

A comprehensive set of measurements on oil-paper interfaces has been carried out, using a number of experimental electrodes, including plane-plane and sphere-sphere geometries (shown in the figure). Because the results of this work were designed to be applicable to power systems, measurements were performed using both 60-Hz voltage and the electric power industry's standard lightning-impulse voltage waveform applied to the electrodes. The work has been reported in detail in NBSIR 80-2071, *Breakdown Between Bare Electrodes with an Oil-Paper Interface* (June 1980).

The data show that when the insulating materials are prepared in accordance with current good industrial practice, breakdown will not necessarily occur at the

*Trans. AIEE, *80*, pp. 365-369, 1961.

interface. In addition, NBS has found that breakdown voltages were not significantly lower for those breakdowns that occurred at the interface than for those which did not. The table presents a summary of data from one set of 78 trials to illustrate this point. At the same time, the experimental results show that breakdown location can move to the interface when either the paper or oil is not prepared properly. For example, breakdown is likely to occur at the interface if the paper is not carefully dried or if many gaseous voids are left in or on the paper. Plans for the future therefore include refinement of the measurement of changes in the electric field geometry under various contaminating conditions.

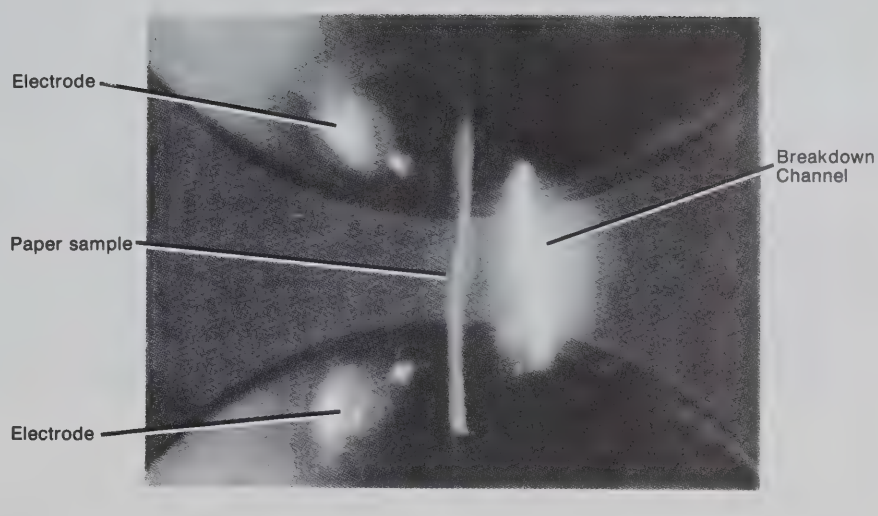

Figure 1—*Electrical breakdown sphere-sphere electrodes. Breakdown did not take place along the paper-oil interface even though the paper was in the region of highest electric field strength.*

SUMMARY OF IMPULSE BREAKDOWN DATA FOR SPHERE-SPHERE ELECTRODES

EXPERIMENTAL CONDITIONS	BREAKDOWN VOLTAGE kV	EFFICIENCY
No interface, oil alone	**173 ± 19**	—
Interface in place but breakdown not at interface	**172 ± 20**	—
Breakdown at interface (all data)	**170 ± 26**	**0.98 ± 0.19**
Breakdown at interface (virgin system)	**173 ± 27**	**1.00 ± 0.19**

NOTES: 1. Uncertainties listed are one standard deviation.
2. The efficiency is the ratio of the breakdown voltage at the interface to the breakdown voltage with no interface in the system.

OPTICAL NONDESTRUCTIVE EVALUATION

The detection and characterization of surface defects is an area of importance in nondestructive evaluation. NBS proposes to determine whether quantitative data, such as defect dimensions, can be obtained from optical scattering data. For this purpose, NBS researchers have been performing both measurements and model calculations of radiation scattered from well-defined shallow grooves in metallic surfaces and comparing theory with experiment.

Albert Feldman and Grady White, Ceramics, Glass, and Solid State Science Division, A251 Materials Building, 301/921-3662.

Researchers in the NBS Center for Materials Science have sought means to detect and characterize surface defects in metals. In the NBS experiments, chopped 10.6 μm radiation from a 3-watt CO_2-laser was incident onto a specimen containing a shallow rectangular groove. The specimens were prepared by scribing grooves into aluminum coatings that had been evaporated onto glass optical flats. Two sets of specimens were used: one set wa used as scribed; the other set was ove coated with an additional thin layer of aluminum. The groove dimensions in both specimen sets were nominally 10, 20, and 50 μm wide by 0.5 μm deep. Figure 1 shows the measured profile of a 50 μm uncoated groove.

The use of 10.6 μm radiation has several advantages: the effect on scattering of surface micro-irregularities is minimized; the fabrication of reasonably well-defined grooves of dimensions comparable to the wavelength is facilitated; and the far field approximation in the model calculations can be used.

A schematic diagram of the measurement apparatus is shown in figure 2. Scattered radiation was measured by a pyroelectric detector that was swung about the specimen in a plane that contained the incident beam and was perpendicular to the groove in the specimen surface. Careful attention was paid to system alignment because certain alignment errors were shown to cause severe distortions of expected scattering patterns.

Model calculations of the expected scattering were performed on the basis of Fraunhofer diffraction theory. The following assumptions were made: the incident beam had a Gaussian intensity distribution; the beam width was significantly larger than the groove width; and the scattering was due to specular reflection from the specimen surface and the groove bottom, but not from the groove walls.

The calculated scattering function obtained was the diffraction pattern of a uniformly illuminated slit but with the intensity uniformly modulated by a factor dependent on the depth of the groove. Figure 3 shows a comparison between experimentally determined scattering and an empirical fit to the data of a single slit diffraction pattern. The points denote the measured scattering intensity of a nominal 50 μm wide uncoated groove as a function of scattering angle. The solid curve is the diffraction pattern of a 52 μm wide slit. Agreement appears to be quite good. Comparable results have been obtained with some of the other grooves; however, with certain grooves, large discrepancies were observed that are attributed to groove irregularities.

Further work is planned to compare scattering from deep grooves with theory and also to study the effect of polarization on the scattering function.

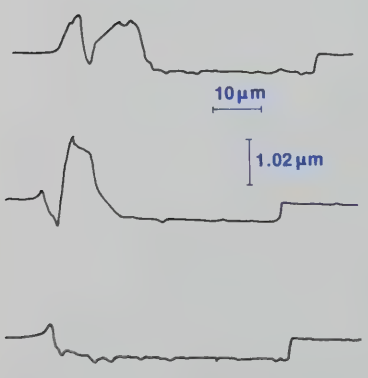

Figure 1—*Upper, middle, and lower cross-sections of uncoated 50 μm groove measured by diamond stylus profilometer.*

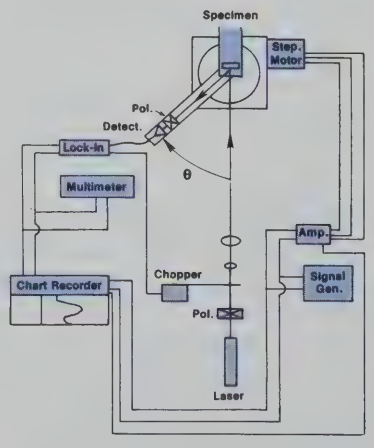

Figure 2—*Schematic diagram of scattering apparatus.*

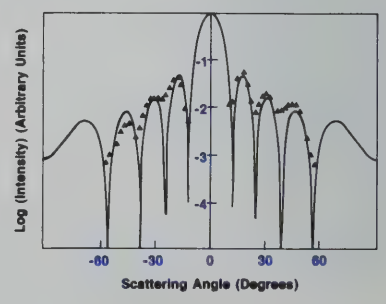

Figure 3—*Logarithm of observed scattering (triangles) from uncoated 50 μm wide specimen superimposed on the calculated logarithm (solid curve) of an ideal single slit diffraction pattern from a 52 μm wide slit.*

TRACE ELEMENTS IN WATER

NBS has issued SRM 1643a, a standard reference material intended primarily for evaluating the accuracy of trace element determinations in filtered and acidified fresh water and for calibrating instrumentation used in these determinations. SRM 1643a approximates the elemental composition of fresh water—27 μg/g calcium, 9 μg/g sodium, 8 μg/g magnesium, and 2 μg/g potassium. Nitric acid is present at a concentration of 0.5 mole per liter to stabilize the trace elements.

The concentrations of the trace elements that were determined are shown in the table. The certified values are based on results obtained either by reference methods of known accuracy or by two or more independent, reliable analytical methods. Some of the analytical methods used are: Atomic absorption spectrometry (electrothermal atomization and vapor generation); flame emission spectrometry; isotope dilution mass spectrometry (thermal ionization); neutron activation (instrumental and radiochemical); photon activation; polarography; and spectrophotometry.

The certification is valid for two years from the shipping date.

Elemental determinations at ng/g levels are limited by contamination. Apparatus is required to be scrupulously cleaned and only the purest grade reagents employed. Samplings and manipulations, such as evaporations, must be done in a clean environment (for example, a Class 100 clean hood).

The technical and support aspects involved in the preparation, certification, and issuance of this Standard Reference Material were coordinated through the Office of Standard Reference Materials by R. Alvarez.

Further information regarding use of this SRM may be obtained from the Office of Standard Reference Materials, B311 Chemistry Building, National Bureau of Standards, Washington, DC 20234.

Concentration of Constituent Elements

Element	Concentration[a] ng/g	Element	Concentration[a] ng/g
Arsenic	76 ± 7	Manganese	31 ± 2
Barium	46 ± 2	Mercury[b]	(<0.2)
Beryllium	19 ± 2	Molybdenum	95 ± 6
Cadmium	10 ± 1	Nickel	55 ± 3
Chromium	17 ± 2	Selenium	11 ± 1
Cobalt	19 ± 2	Silver	2.8 ± 0.3
Copper	18 ± 2	Strontium	239 ± 5
Iron	88 ± 4	Vanadium	53 ± 3
Lead	27 ± 1	Zinc	72 ± 4

[a] The estimated uncertainty is based on judgment and represents an evaluation of the combined effects of method imprecision and possible systematic errors among methods. (No attempt was made to derive exact statistical measures of imprecision because several methods were involved in the determination of the constituents.) To convert to nanograms per milliliter, multiply by the density of the SRM, which, at 23 °C, is 1.017 grams per milliliter.

[b] Mercury is *not certified*. Gold had been added at a concentration of 15 ng/mL in an attempt to stabilize the mercury added at a concentration of 1 ng/mL.

CONFERENCES

For general information on NBS conferences, contact JoAnn Lorden, NBS Public Information Division, Washington, DC 20234, 301/921-2721.

CONFERENCE ON PRECISION MEASUREMENT AND FUNDAMENTAL CONSTANTS

The National Bureau of Standards will host the Second International Conference on Precision Measurement and Fundamental Constants at NBS headquarters in Gaithersburg, MD, from June 8 to 12, 1981.

Conference organizers hope to provide an international forum for scientists actively engaged in experimental and theoretical research on precision measurements relating to the fundamental physical constants and to the testing of related theory. The last such comprehensive international meeting was held at NBS in August 1970.

One goal of the 1981 Conference will be to gather additional data for the 1981 adjustment of the values of the fundamental constants recommended for international use. This adjustment (using the least-squares method) is being carried out by the Task Group on Fundamental Constants of the Committee on Data for Science and Technology (CODATA).

Topics to be discussed include the absolute realization of basic measurement units; measurements of fundamental atomic constants such as the Rydberg, the fine-structure, and the gravitational constants; and high-precision tests of quantum electrodynamics and similar fundamental theories. Emphasis is placed on assessment of the present state of precision measurement, basic limitations, and possible future avenues for advances.

The official sponsors of PMFC-II are:

- International Union of Pure and Applied Physics (IUPAP)
- Committee on Data for Science and Technology of the International Council of Scientific Unions (CODATA)
- U.S. National Academy of Sciences/National Research Council, Committee on Fundamental Constants (NAS/NRC)
- International Bureau of Weights and Measures (BIPM)
- U.S. National Bureau of Standards

Those interested in attending the 1981 Conference or who need more information should contact Barry N. Taylor, B258 Metrology Building, NBS, Washington, DC 20234, 301/921-2701.

JOINT INTERNATIONAL CONFERENCE

Joint Conferences including the Symposia on Thermophysical Properties, the Conferences on Thermal Conductivity, and the Thermal Expansion Symposia will be held simultaneously June 15-19, 1981, at the National Bureau of Standards, Gaithersburg, Maryland, to maximize the effectiveness of each conference, although the identity of the individual conferences will be preserved. The joint conferences will provide the thermophysics community with a forum for presentations and discussion of research activities in all areas of thermophysical properties. The organization of the conferences is coordinated by the International Thermophysics Congress. Sponsors are: NBS; Committee on Thermophysical Properties, Heat Transfer Division, American Society of Mechanical Engineers; and the Center for Information and Numerical Data Analysis and Synthesis (CINDAS), Purdue University.

The conferences are concerned with theoretical, experimental, and applied aspects of thermophysical properties of matter in solid, liquid, and gaseous states. Some of the appropriate topics are:

- Thermodynamic properties, including heat capacity, enthalpy, thermal expansion, vapor pressure, surface tension, and other properties related to phase changes, PVT, and calorimetric studies.
- Transport properties, including thermal and electrical conductivity, thermal diffusivity, viscosity and related properties.
- Thermal radiative properties, including emittance, absorptance, reflectance, and optical constants.
- New developments in experimental techniques.
- Reviews of current status of theory on thermophysical properties.
- Reports on reference materials and critical evaluation and standardization of techniques and procedures for thermophysical measurements.
- Reference data-correlation and evaluation techniques.
- Fluid mixtures, composites, aggregates, and alloys.
- Selected technological applications of thermophysical properties including energy technology.

For general joint conference information, contact Kathy Stang, B348 Materials Building, NBS, Washington, DC 20234, phone 301/921-3295.

CONFERENCE CALENDAR

December 10
COMPUTER NETWORKING SYMPOSIUM, NBS, Gaithersburg, MD; sponsored by NBS and IEEE; contact: Robert Toense, B226 Technology Building, 301/921-3516.

1981

March 2-4
MEASUREMENT OF ELECTRICAL QUANTITIES IN PULSE POWER SYSTEMS, NBS, Boulder, CO; sponsored by NBS; contact: Ronald McKnight, B344 Metrology Building, 301/921-3121.

March 17-18
SECOND CONFERENCE ON CONSUMER PRODUCT STANDARDS, NBS, Gaithersburg, MD; sponsored by NBS and ASTM; contact: Walter Leight, 111 EM Building, 301/921-3750.

March 23-24
ADP SECURITY AND AUDITING, NBS, Gaithersburg, MD; sponsored by NBS and Federal ADP Users Group; contact: T. C. Lowe, A265 Technology Building, 301/921-2750.

April 6-10
6TH INTERNATIONAL SYMPOSIUM ON NOISE IN PHYSICAL SYSTEMS, NBS, Gaithersburg, MD; sponsored by NBS and the Catholic University of America; contact: Robert J. Soulen, B128 Physics Building, 301/921-2018.

***April 21-24**
MECHANICAL FAILURES PROCESSING GROUP, NBS, Gaithersburg, MD; sponsored by NBS and MFPG; contact: H. Burnett, B266 Materials Building, 301/921-2992.

April 30-May 1
NATIONAL ROOFING TECHNOLOGY CONFERENCE, NBS, Gaithersburg, MD; sponsored by NBS and NRCA; contact: Robert Mathey, B348 Building Research Building, 301/921-2629.

June 1-3
6TH INTERNATIONAL SYMPOSIUM ON IMAGING AND ULTRASONIC TISSUE CHARACTERISTICS, NBS, Gaithersburg, MD; sponsored by NBS, NIH, IEEE, and AIUM; contact: Melvin Linzer, A366 Materials Building, 301/921-2611.

June 8-12
SECOND INTERNATIONAL CONFERENCE ON PRECISION MEASUREMENTS AND FUNDAMENTAL CONSTANTS, NBS, Gaithersburg, MD; sponsored by NBS, IUPAP, and AMCO; contact: Barry N. Taylor, B258 Metrology Building, 301/921-2701.

June 15-19
INTERNATIONAL JOINT CONFERENCE ON THERMOPHYSICAL PROPERTIES, NBS, Gaithersburg, MD; sponsored by NBS, ASME, and Purdue University; contact: A. Cezairliyan, Room 124 Hazards Building, 301/921-3687.

June 18
20TH ANNUAL ACM SYMPOSIUM, UNIVERSITY OF MARYLAND, College Park, MD; sponsored by NBS and ACM; contact: Wilma Osborne, A265 Technology Building, 301/921-3485.

September 14-16
SECOND INTERNATIONAL CONFERENCE ON THE DURABILITY OF BUILDING MATERIALS AND COMPONENTS, NBS, Gaithersburg, MD; sponsored by NBS, ASTM, NRC of Canada, International Council for Building Research Studies and Documentation, International Union of Testing and Research Laboratories for Materials and Structures; contact: Geoffrey Frohnsdorff, B348 Technology Building, 301/921-3458.

October 7-9
36TH CALORIMETRY CONFERENCE, NBS, Gaithersburg, MD; sponsored by NBS and University of Colorado; contact: Robert Goldberg, A303 Physics Building, 301/921-2752.

October 13-15
6TH ANNUAL CONFERENCE ON MATERIALS FOR COAL CONVERSION AND UTILIZATION, NBS, Gaithersburg, MD; sponsored by NBS, DOE, EPRI, and GRI; contact: Samuel Schneider, B308 Materials Building, 301/921-2894.

*New Listings

BUILDING TECHNOLOGY PUBLICATIONS CATALOGED

*Porterfield, K., Ed., Building Technology Publications, Nat. Bur. Stand. (U.S.), Spec. Publ. 457-4, 74 pages (June 1980) Stock No. 003-003-02205-5, $3.75.**

Research by the National Bureau of Standards Center for Building Technology in 1979 resulted in approximately 150 publications and papers on leading subjects ranging from energy conservation to structural safety and architectural design.

This literature, offering a glimpse of the future as well as a perspective on the current world of building and construction, is now cataloged in *Building Technology Publications—Supplement 4: 1979* (SP 457-4).

The new catalog is the fourth supplement to *Building Technology Publications 1965-1975* (SP 457). For the calendar year 1979, it includes titles and abstracts of each NBS publication and each paper published in non-NBS media, key word and author indexes, and general information and instructions on ordering publications of the Center for Building Technology.

By selecting a main word or subject in the alphabetically arranged key word index, users of the catalog can locate reports of interest in a wide variety of subject areas.

BUILDING STRUCTURAL STRENGTH REQUIREMENTS

Ellingwood, B., Development of a Probability Based Load Criterion for American National Standard A58, Nat. Bur. Stand. (U.S.), Spec. Publ. 577, 228 pages (June 1980) Stock No. 003-003-02200-4, $6.

Researchers at the National Bureau of Standards have developed a new method for specifying the structural strength requirements of buildings regardless of the construction materials used. With this new system of probability-based load factors and load combinations, the design loads for a building can be related specifically to required levels of reliability against structural failure or unserviceability. Consequently, the new system could alter current building codes and structural designs developed in the future.

Currently, building codes specify minimum structural requirements according to materials used. Different load and resistance factors—or different allowable stresses—are required for different materials. This diversity has complicated the building design process, especially in designs calling for a mixture of construction materials.

With the new load criterion, developed under the supervision of Dr. Bruce Ellingwood, a structural engineer at the NBS Center for Building Technology, a unified design approach is used whereby the structural loads for design of a building can be calculated regardless of the materials used—wood, masonry, steel, concrete, or other materials. This approach is called "probabilistic limit states design," a design technique allowing the accurate estimation of conditions where a structure fails to achieve its intended purpose in some manner (collapse, excessive deflation).

The new, unified design approach should result in a more rational and consistent framework for standards writers to use with fewer subjective decisions. This is especially important for innovative structural materials and schemes where there is little experience upon which to base design criteria. It should also simplify the designer's task in analyzing building loads. Rather than performing a separate load analysis for each material used in a particular structure, designers would only need to carry out a single analysis.

Ellingwood says that future standards and the codes based on them (which incorporate the new calculation technique) would be less likely to lead to overly conservative safety provisions in buildings. Provisions that are inadequate from a safety point of view could also be avoided more easily through use of the new load criterion. He speculates that masonry and wood structures would be affected most by changes resulting from use of the new NBS design calculation technique. Buildings in which a proportionately high cost lies in the structural system—such as aircraft hangars and industrial buildings—might also be significantly affected in future designs, Ellingwood suggests. "Small changes of performance criteria can mean major changes in costs for such buildings," he says.

The new load criterion was developed over a 5-year span and utilizes existing field and laboratory data, some of which have been developed at NBS. For example, research at NBS involving live and wind loads formed the basis of portions of the new structural safety tool. The new load criterion is under review by the American National Standard Committee A58. Comments from design professionals will also be solicited and evaluated. If adopted, the method would become a part of the national ANSI A58 Standard, which defines the amount of dead (structural), live (movable), wind, snow, and earthquake loads suitable for inclusion in the thousands of building codes and other regulatory documents.

The research is detailed in a recent NBS publication, *Development of a Probability Based Load Criterion for American National Standard A58* (SP 577). Assisting Ellingwood in the project were Theodore V. Galambos of Washington University, St. Louis, MO; James G. MacGregor, of the University of Alberta, Edmonton, Alberta; and C. Allin Cornell of the Massachusetts Institute of Technology, Cambridge, MA.

*Publications cited here may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402 (foreign: add 25 percent). Microfiche copies are available from the National Technical Information Service, Springfield, VA 22161. For complete periodic listings of all scientific papers and articles produced by NBS staff, write: Editor, Publications Newsletter, Administration Building, National Bureau of Standards, Washington, DC 20234.

BUILDING MATERIALS AND COMPONENTS

Frohnsdorff, G., Masters, L. W., and Martin, J. W., An Approach to Improved Durability Tests for Building Materials and Components, Nat. Bur. Stand. (U.S.), Tech. Note 1120, 35 pages (July 1980) Stock No. 003-003-02213-6, $2.25.

Durability tests usually provide relative measures of the time building materials and components will perform their intended functions under the expected service conditions. This is not adequate to ensure the proper selection of new building materials and components because quantitative measures of long-term performance are needed. Although many tests have been developed to accelerate degradation processes of building materials, they are seldom fully adequate for reliable prediction of long-term performance.

This report outlines a recommended practice (ASTM E 632-78) based on National Bureau of Standards research that provides a framework for the development of improved durability tests. The application of the recommended practice, which does not specify an analysis procedure, is illustrated by examples from the literature that use both deterministic and probabilistic approaches.

While probabilistic concepts have not been applied extensively to materials durability problems in the construction industry, the authors suggest that these concepts offer new opportunities for obtaining improved quantitative predictions of the service life of building materials.

LIGHTING DESIGN

Rubin, A. I., Lighting Issues in the 1980's, Nat. Bur. Stand. (U.S.), Spec. Publ. 587, 175 pages (July 1980) Stock No. 003-003-02218-7, $5.50.

The state-of-the-art in lighting and issues to be faced in the new decade are discussed by nine prominent panelists and a number of invited experts in *Lighting Issues in the 1980's* (SP 587), a new National Bureau of Standards publication.

The 175-page volume summarizes the proceedings and provides a complete transcript of a lighting roundtable cosponsored by NBS and the Illuminating Engineering Society of North America.

Issues addressed by the panelists and auditors include: energy conservation; illumination levels; lighting design; lighting education; lighting research; post-occupancy evaluation; power budget; task lighting; visual performance; and biological effects.

PUBLICATIONS LISTING

Building Technology

Berry, S. A., Ed., Research and Innovation in the Building Regulatory Process. Proceedings of the Fourth NBS/NCSBCS Joint Conference held in St. Louis, MO, on Sept. 11, 1979, in Conjunction with the Twelfth Annual Meeting of the National Conference of States on Building Codes and Standards (NCSBCS), Nat. Bur. Stand. (U.S.), Spec. Publ. 586, 261 pages (June 1980) Stock No. 003-003-02212-8, $7.

Raufaste, N., and Olmert, M., Eds., Building Technology Project Summaries 1979-1980, Nat. Bur. Stand. (U.S.), Spec. Publ. 446-4, 79 pages (July 1980) Stock No. 003-003-02236-5, $4.

Computer Science and Technology

Wampler, R. H., Problems Used in Testing the Efficiency and Accuracy of the Modified Gram-Schmidt Least Squares Algorithm, Nat. Bur. Stand. (U.S.), Tech. Note 1126, 83 pages (Aug. 1980) Stock No. 003-003-0021-7, $4.

Health and Safety

Canada, T. R., and Carpenter, B. S., Eds., Measurement Technology for Safeguards and Materials Control. Proceedings from American Nuclear Society Topical Meeting held at Kiawah Island, SC, Nov. 26-30, Nat. Bur. Stand. (U.S.), Spec. Publ. 582, 769 pages (June 1980) Stock No. 003-003-02207-1, $11.

Energy Conservation and Production

Didion, D., Garvin, D., and Snell, J., A Report on the Relevance of the Second Law of Thermodynamics to Energy Conservation, Nat. Bur. Stand. (U.S.), Tech. Note 1115, 51 pages (Aug. 1980) Stock No. 003-003-02231-4, $3.25.

Engineering, Product, and Information Standards

Advanced Data Communication Control Procedures (ADCCP), Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 71, 4 pages (May 1980).

Lasers and Their Applications

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NEWS BRIEFS

NEW METHOD FOR CLEANING LIQUID METAL SURFACES. A metallurgist and surface scientist at NBS have developed a new technique for producing clean liquid metal surfaces. These researchers found that by bombarding a liquid gallium surface with a beam of argon ions, impurities such as gallium oxide and carbon particulates could be efficiently removed. Although the width of the argon beam covered only about one tenth of the surface area of the liquid drop being studied, the researchers found that impurities were drawn into the beam from the entire surface and sputtered away. NBS has used the new ion bombardment technique ultra-high vacuum to make precise liquid-vapor surface tension measurements which have application for the processing of ultra-pure materials in space.

OPTICAL FIBER MEASUREMENTS. Ten optical fiber manufacturers working with the Optical Electronic Metrology group at the NBS Boulder Laboratories are participating in an interlaboratory measurement comparison of attenuation, bandwidth, and numerical aperture. The measurements will test procedures under consideration by the Electronics Industry Association's Working Group P6.6 on Optical Fibers. This is the second interlaboratory measurement comparison on optical fibers sponsored by NBS.

NEW APPARATUS FOR TESTING FULL-SCALE WALL SECTIONS. A contract has been awarded for the construction of a new test apparatus that will enable researchers in the NBS Center for Building Technology to measure simultaneously the heat, air, and moisture flow in full-scale wall sections. Known as a calibrated hot box, the apparatus will accommodate walls 3 meters high and 5 meters wide, permitting measurements on sections with thermal resistances of up to R-50. The NBS facility will permit very accurate actual measurements under carefully controlled and monitored conditions, advancing the state of the art in such thermal measurements. The work is being funded jointly by NBS and the Department of Energy.

TWO FEDERAL INFORMATION PROCESSING STANDARDS APPROVED. Commerce Secretary Philip M. Klutznick has approved Federal Information Processing Standards (FIPS) for microfilm readers (FIPS PUB 84) and optical character recognition (OCR) inks (FIPS PUB 85). Defining the minimum acceptable image quality for microfilm reading devices used for display of computer output microforms, FIPS PUB 84 is designed to facilitate information interchange when the information is recorded on microforms generated by computer systems. FIPS PUB 85 is addressed to the need of OCR systems for a high contrast between data characters to be read and the paper.

HUMAN SERUM SRM. NBS recently issued a Human Serum Standard Reference Material (SRM) which should significantly improve the accuracy of many of the more than 4 billion measurements made annually by hospitals and clinical laboratories to diagnose and treat health problems. SRM 909 consists of six vials of freeze-dried human serum and six vials of high purity water to reconstitute the serum. The SRM certificate lists certified concentration values for calcium, chloride, glucose, lithium, potsssium, and uric acid. In early 1981 additional certified concentrations will be provided for cholesterol and urea, along with the activity levels of several important enzymes determined by "best available" methods. SRM 909 is available for $149 per unit through the Office of Standard Reference Materials, B311 Chemistry Building, NBS, Washington, DC 20234.

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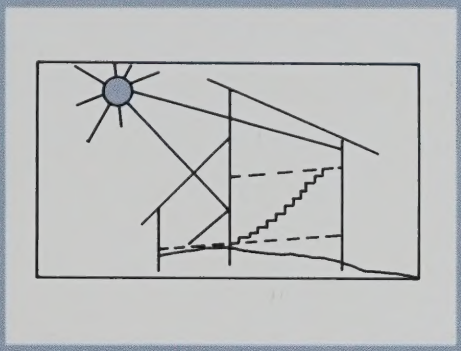

Certain building codes may present obstacles to the growing use of passive solar technology. December DIMENSIONS describes some considerations that may affect its success and popularity.

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